CHEMICAL AND BACTERIOLOGICAL (BIOLOGICAL) WEAPONS AND THE EFFECTS OF THEIR POSSIBLE USE

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Department of Political
and Security Council Affairs

CHEMICAL AND BACTERIOLOGICAL (BIOLOGICAL) WEAPONS AND THE EFFECTS OF THEIR POSSIBLE USE

REPORT OF THE SECRETARY-GENERAL

UNITED NATIONS
New York, 1969

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FOREWORD

During the past few years, I have become increasingly concerned by developments in the field of chemical and bacteriological (biological) weapons and have given expression to this concern on several occasions. A year ago, I stated publicly that "the international community was not sufficiently conscious of the danger inherent in this new type of weapon of mass murder", and that "due attention had not been focused on this very serious problem". In the introduction to my annual report on the work of the Organization, in September 1968, I stated:

> While progress is being made in the field of nuclear disarmament, there is another aspect of the disarmament problem to which I feel too little attention has been devoted in recent years. The question of chemical and biological weapons has been overshadowed by the question of nuclear weapons, which have a destructive power several orders of magnitude greater than that of chemical and biological weapons. Nevertheless, these too are weapons of mass destruction regarded with universal horror. In some respects, they may be even more dangerous than nuclear weapons because they do not require the enormous expenditure of financial and scientific resources that are required for nuclear weapons. Almost all countries, including small ones and developing ones, may have access to these weapons, which can be manufactured quite cheaply, quickly and secretly in small laboratories or factories. This fact in itself makes the problem of control and inspection much more difficult. Moreover, since the adoption, on 17 June 1925, of the Geneva Protocol for the Prohibition of the Use in War of Asphyxiating, Poisonous or Other Gases and of Bacteriological Methods of Warfare, there have been many scientific and technical developments and numerous improvements, if that is the right word, in chemical and biological weapons, which have created new situations and new problems. On the one hand, there has been a great increase in the capability of these weapons to inflict unimaginable suffering, disease and death to ever larger numbers of human beings; on the other hand, there has been a growing tendency to use some chemical agents for civilian riot control and a dangerous trend to accept their use in some form in conventional warfare.

Two years ago, by resolution 2162 B (XXI), the General Assembly called for the strict observance by all States of the principles and objectives of the Geneva Protocol of 1925, condemned all actions contrary to those objectives and invited all States to accede to the Protocol. Once again, I would like to add my voice to those of others in urging the early and complete implementation of this resolution. However, in my opinion, much more is needed.

At its twenty-third session, by resolution 2454 A (XXIII), the General Assembly requested me to prepare, with the assistance of qualified consultant experts, a report on chemical and bacteriological (biological) weapons in accordance with the proposal contained in the introduction to my annual report on the work of the Organization and in accordance with the recommendation contained in the report of the Conference of the Eighteen-Nation Committee on Disarmament of 4 September 1968.

In pursuance of this resolution, I appointed the following group of fourteen consultant experts to assist me in the preparation of the report: Dr. Tibor Bakacs, Professor of Hygiene, Director-General of the National Institute of Public Health, Budapest; Dr. Hotse C. Bartlema, Head of the Microbiological Department of the Medical-Biological Laboratory, National Defence Research Organization TNO, Rijswijk, Netherlands; Dr. Ivan L. Bennett, Director of the New York University Medical Center and Vice-President of Medical Affairs, New York University, New York; Dr. S. Bhagavantam, Scientific Adviser to the Minister of Defence, New Delhi; Dr. Jiri Franek, Director of the Military Institute for Hygiene, Epidemiology and Microbiology, Prague; Dr. Yosio Kawakita, President of University of Chiba, Professor of Bacteriology, Chiba City, Japan; M. Victor Moulin, *Ingénieur en chef de l'armement, Chef du Bureau Défense chimique et biologique, Direction technique des armements terrestres*, Saint-Cloud, France; Dr. M. K. McPhail, Director of Chemical and Biological Defence, Defence Chemical, Biological and Radiation Laboratories, Defence Research Board, Ottawa; Academician O. A. Reutov, Professor of Chemistry at the Moscow State University, Moscow; Dr. Guillermo Soberón, Director, *Instituto de Investigaciones Biomédicas, Universidad Nacional Autónoma de México*, Mexico City; Dr. Lars-Erik Tammelin, Chief of Department for Medicine and Chemistry, Research Institute for National Defence, Stockholm; Dr. Berhane Teoume-Lessane, Medical Co-Director and Head of Department of Viruses and Rickettsiae, Imperial Central Laboratory and Research Institute, Addis Ababa; Colonel Zbigniew Zoltowski, Professor of Medicine, Epidemiologist and Scientific Adviser to the Ministry of National Defence, Warsaw; Sir Solly Zuckerman, Chief Scientific Adviser to the Government of the United Kingdom, Professor Emeritus, University of Birmingham.

Mr. William Epstein, Director of the Disarmament Affairs Division, Department of Political and Security Council Affairs, served as Chairman of the Group of Consultant Experts. Mr. Alessandro Corradini, Chief of the Committee and Conference Services Section, acted as Secretary of the Group. He was assisted by members of the Disarmament Affairs Division.

After giving due consideration to the terms of the resolution and to the views expressed and the suggestions made during the discussion of the question at the twenty-third session of the General Assembly, I reached the conclusion that the aim of the report should be to provide a scientifically sound appraisal of the effects of chemical and bacteriological (biological) weapons and should serve to inform Governments of the consequences of their possible use. Within this over-all framework, the report would furnish accurate information in a concise and readily understandable form on the following matters: the basic characteristics of chemical and bacteriological (biological) means of warfare; the probable effects of chemical and bacteriological (biological) weapons on military and civil personnel, both protected and unprotected; the environmental factors affecting the employment of chemical and bacteriological (biological) means of warfare; the possible long-term effects on human health and ecology; and the economic and security implications of the development, acquisition and possible use of chemical and bacteriological (biological) weapons and of systems for their delivery.

The consultant experts to whom I conveyed these terms of reference accepted them as the basis for their study.

It was my intention that the Group of Consultant Experts should survey the entire subject from the technical and scientific points of view, so that the report could place these weapons in proper perspective. It was also my hope that an authoritative report could become the basis for political and legal action by the Members of the United Nations.

As the report was to be made available by 1 July 1969, very concentrated efforts by the consultant experts were required in order to cover this extensive field. The members of the Group, acting in their personal capacities, carried out this demanding task at three sessions between January and June 1969.

The Group had the benefit of valuable submissions from the World Health Organization, the Food and Agriculture Organization, the International Committee of the Red Cross, the Pugwash Conference on Science and World Affairs (Pugwash) and the International Institute for Peace and Conflict Research (SIPRI). I wish to express my grateful appreciation to all the consultant experts for their dedicated work and to the organizations and bodies who co-operated in the preparation of the study.

The Group has submitted to me a unanimous report embodying its findings and conclusions. I wish to avail myself of this opportunity to express my gratification for the very high level of competence with which the consultant experts have discharged their mandate. In a very short period of time, they have produced a study, which, in spite of the many complex aspects of the subject matter, is both concise and authoritative. It is a document which, I believe, provides valuable insights into the grave dangers that are posed by the production and possible use of these dreaded weapons.

I am particularly impressed by the conclusion of the consultant experts wherein they state:

> The general conclusion of the report can thus be summed up in a few lines. Were these weapons ever to be used on a large scale in war, no one could predict how enduring the effects would be, and how they would affect the structure of society and the environment in which we live. This overriding danger would apply as much to the country which initiated the use of these weapons as to the one which had been attacked, regardless of what protective measures it might have taken in parallel with its development of an offensive capability. A particular danger also derives from the fact that any country could develop or acquire, in one way or another, a capability in this type of warfare, despite the fact that this could prove costly. The danger of the proliferation of this class of weapons applies as much to the developing as it does to developed countries.
>
> The momentum of the arms race would clearly decrease if the production of these weapons were effectively and unconditionally banned. Their use, which could cause an enormous loss of human life, has already been condemned and prohibited by international agreements, in particular the Geneva Protocol of 1925, and, more recently, in resolutions of the General Assembly of the United Nations. The prospects for general and complete disarmament under effective international control, and hence for peace throughout the world, would brighten significantly if the develment, production and stockpiling of chemical and bacteriological (biological) agents intended for purposes of war were to end and if they were eliminated from all military arsenals.
>
> If this were to happen, there would be a general lessening of international fear and tension. It is the hope of the authors that this report will contribute to public awareness of the profoundly dangerous results if these weapons were ever used, and that an aroused public will demand and receive assurances that Governments are working for the earliest effective elimination of chemical and bacteriological (biological) weapons.

I have given the study prepared by the consultant experts my earnest consideration, and I have decided to accept their unanimous report in its entirety and to transmit it to the General Assembly, the Security Council, the Eighteen-Nation Committee on Disarmament and to the Governments of Member States, as the report called for by resolution 2454 A (XXIII).

I also feel it incumbent upon me, in the hope that further action will be taken to deal with the threat posed by the existence of these weapons, to urge that the Members of the United Nations undertake the following measures in the interests of enhancing the security of the peoples of the world:

1. To renew the appeal to all States to accede to the Geneva Protocol of 1925;

2. To make a clear affirmation that the prohibition contained in the Geneva Protocol applies to the use in war of all chemical, bacteriological and biological agents (including tear gas and other harassing agents) which now exist or which may be developed in the future;

3. To call upon all countries to reach agreement to halt the development, production and stockpiling of all chemical and bacteriological (biological) agents for purposes of war and to achieve their effective elimination from the arsenal of weapons.

U THANT
Secretary-General

LETTER OF TRANSMITTAL

30 June 1969

Dear Mr. Secretary-General,

I have the honour to submit herewith a unanimous report on chemical and bacteriological (biological) weapons which was prepared in pursuance of General Assembly resolution 2454 A (XXIII).

The Consultant Experts appointed in accordance with the General Assembly resolution were the following:

Dr. Tibor BAKACS
Professor of Hygiene, Director-General of the National Institute of Public Health, Budapest.

Dr. Hotse C. BARTLEMA
Head of the Microbiological Department of the Medical-Biological Laboratory, National Defence Research Organization TNO, Rijswijk, Netherlands.

Dr. Ivan L. BENNETT
Director of the New York University Medical Center and Vice-President for Medical Affairs, New York University, New York.

Dr. S. BHAGAVANTAM
Scientific Adviser to the Minister of Defence, New Delhi.

Dr. Jiri FRANEK
Director of the Military Institute for Hygiene, Epidemiology and Microbiology, Prague.

Dr. Yosio KAWAKITA
President of the University of Chiba, Professor of Bacteriology, Chiba City, Japan.

M. Victor MOULIN
Ingénieur en chef de l'armement, Chef du Bureau Défense chimique et biologique, Direction technique des armements terrestres, Saint-Cloud, France.

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Colonel Zbigniew ZOLTOWSKI

Professor of Medicine, Epidemiologist and Scientific Adviser to the Ministry of National Defence, Warsaw.

Sir Solly ZUCKERMAN

Chief Scientific Adviser to the Government of the United Kingdom, Professor Emeritus, University of Birmingham.

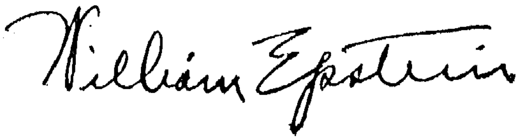
The report was drafted during sessions held in Geneva between 20 and 24 January and between 16 and 29 April and finalized at meetings held in New York between 2 and 14 June 1969.

The Group of Consultant Experts wishes to acknowledge the assistance it received from the World Health Organization, the Food and Agriculture Organization, the International Committee of the Red Cross, the Pugwash Conference on Science and World Affairs (Pugwash) and the International Institute for Peace and Conflict Research (SIPRI), all of which submitted valuable information and material for the purposes of the study.

The Group of Consultant Experts also wishes to express its gratitude for the valuable assistance it received from members of the United Nations Secretariat.

I have been requested by the Group of Consultant Experts, as its Chairman, to submit its unanimous report to you on its behalf.

Yours sincerely,



William EPSTEIN, Chairman
Group of Consultant Experts on Chemical and Bacteriological (Biological) Weapons

INTRODUCTION

1. In accordance with General Assembly resolution 2454 A (XXIII) the Secretary-General was asked to prepare, with the assistance of qualified consultant experts, a report on chemical and bacteriological (biological) weapons and on the effects of their possible use. Specifically, the experts were asked to provide a scientific appraisal of the characteristics of the chemical and bacteriological (biological) weapons which could be used in warfare, of the effects they could have on military personnel and civilians, as well as of their long-term effects on health and our physical environment. They were also asked to provide a statement about the economic and security implications of the development, acquisition and possible use of such weapons and associated weapon systems. The report which follows is confined to these objectives.

2. No form of warfare has been more condemned than has the use of this category of weapons. The poisoning of wells has been regarded from time immemorial as a crime incompatible with the rules of war. "War is waged with weapons, not with poison" ("*Armis bella non venenis geri*"), declared the Roman jurists. As the destructive power of arms increased over the years, and with it the potential for the widespread use of chemicals, efforts were made to prohibit through international understandings and by legal means the use of chemical weapons. The Brussels Declaration of 1874 and the Hague Conventions of 1899 and 1907 prohibited the use of poisons and poisoned bullets, and a separate declaration of the Hague Convention of 1899 condemned "the use of projectiles the sole object of which is the diffusion of asphyxiating or deleterious gases".

3. The fear today is that the scientific and technological advances of the past few decades have increased the potential of chemical and bacteriological (biological) weapons to such an extent that one can conceive of their use causing casualties on a scale greater than one would associate with conventional warfare. At the moment most of our knowledge concerning the use of chemical weapons is based upon the experience of the First World War. Gas was first used in 1914, and the first big attack in 1915 claimed 5,000 human lives. It is estimated that from then until the end of the war in 1918, at least 125,000 tons of toxic chemicals were used, and according to official reports gas casualties numbered about 1,300,000, of which about 100,000 were fatal. The agents used in that war were much less toxic than those, in particular nerve agents, which could be used today, and they were

dispersed by means of relatively primitive equipment as compared with what is now available and in accordance with battlefield concepts of a relatively unsophisticated kind.

4. It is true that a considerable effort has also been made to develop chemical agents which have as their purpose not to kill but to reduce a man's capacity to fight. Such agents are used by civil authorities of a number of countries in order to suppress disorders and to control riots, but when used in warfare they would inevitably be employed as an adjunct to other forms of attack, and their over-all effect might be lethal.

5. Since the Second World War, bacteriological (biological) weapons have also become an increasing possibility. But because there is no clear evidence that these agents have ever been used as modern military weapons, discussions of their characteristics and potential threat have to draw heavily upon experimental field and laboratory data and on studies of naturally occurring outbreaks and epidemics of infectious disease, rather than on direct battlefield experience. Their potential importance in warfare can be sensed when one remembers that infectious disease, even as late as the Second World War, caused numerous casualties.

6. The greater threat posed by chemical weapons today derives from the discovery and manufacture of new, more toxic compounds. On the other hand, bacteriological (biological) agents already exist in nature and can be selected for use in warfare. Some of these agents, notably bacteria, have been known for several decades, but there is a vast number of other possible agents, especially viruses, which have been discovered only recently, and some of these also possess characteristics which make their use possible in war. Increases in potency of these various types of agent have been made possible by scientific and technological advances in microbial genetics, experimental pathology and aerobiology.

7. As is well known, the use of toxic gases in the First World generated so powerful a sense of outrage that countries were encouraged to adopt measures prohibiting both chemical and bacteriological (biological) weapons. The result was the Geneva Protocol of 17 June 1925, which prohibits the use in war of asphyxiating, poisonous or other gases and of all analogous liquids, materials or devices, as well as bacteriological methods of warfare. This established a custom and hence a standard of international law, and in practice most States have adhered to the principle that no one should resort to the use of such weapons. But despite the abhorrence in which they have always been held by civilized peoples, chemical weapons have none the less on occasion been used. For example, mustard gas was used in Ethiopia in 1935-1936, causing numerous casualties amongst troops and a civilian population which was not only completely unprotected but lacked even the most elementary medical services. It should also be noted that the existence of the Geneva

Protocol of 1925 may have helped as a deterrent to the use of chemical or bacteriological (biological) weapons in the Second World War, even though the belligerents in that conflict had developed, produced and stockpiled chemical agents for possible use. The International Tribunal at Nuremberg brought into the open the fact that amongst the new agents which had been produced and stockpiled during the course of the war were such highly lethal agents as Tabun and Sarin. Since then the validity and effectiveness of the Geneva Protocol have been reinforced by the approval, by the General Assembly of the United Nations, without a single dissenting voice, of resolutions 2162 B (XXI) of 5 December 1966 and 2454 A (XXIII) of 20 December 1968, calling for "strict observance by all States of the principles and objectives" of the Geneva Protocol and inviting all States to accede to it.

8. It is simple to appreciate the resurgence of interest in the problems of chemical and bacteriological (biological) warfare. Advances in chemical and biological science, while contributing to the good of mankind, have also opened up the possibility of exploiting the idea of chemical and bacteriological (biological) warfare weapons, some of which could endanger man's future, and the situation will remain threatening so long as a number of States proceed with their development, perfection, production and stockpiling.

9. The report, as is noted in the General Assembly resolution, is designed to submit to peoples and Governments, in a form easily understood by them, information on the effects of the possible use of chemical and bacteriological (biological) weapons, as well as to promote a further consideration of problems connected with chemical and bacteriological (biological) weapons. Information about the nature of chemical and bacteriological (biological) weapons, about their increase and diversification as technology has advanced, about their long-term effects on human beings, animals and vegetation, and about environmental factors which condition these effects, is provided in chapters I to IV of the report. In chapter V, which deals with the economic and security implications of chemical and bacteriological (biological) warfare, the experts have interpreted the word "security" to mean both security in the narrow military sense and security in terms of the adverse and long-term effects which these weapons, if they were ever used, could have on the framework of civilized existence.

10. As the present report shows, the outstanding characteristics of this class of weapons, particularly bacteriological (biological) weapons, is the variability, amounting under some circumstances to unpredictability, of their effects. Depending on environmental and meteorological conditions, and depending on the particular agent used, the effects might be devastating or negligible. They might be localized or widespread. They might bear not only on those attacked but on those who initiated their use, whether or not the attacked military forces retaliated in kind. Civilians would be even more vulnerable than the

military. The development, acquisition and deployment of chemical and bacteriological (biological) weapons—quite apart from questions of protection—constitutes a real economic burden which varies in extent for different countries. Above all, their acquisition could not possibly obviate the need for other weapons.

11. As chapters I and V of the report indicate, it would be enormously costly in resources, and administratively all but impossible, to organize adequate protection for a civilian population against the range of possible chemical agents. Even military personnel, if locally engaged in a particular operation in which chemical and/or bacteriological (biological) weapons were used and where they had the advantage of protective measures, would be unlikely to escape the widerspread and longer-term effects on their country at large. These might arise, for example, from the impracticability of protecting soil, plants, animals and essential food crops against short- and long-term effects.

12. To appreciate the risks that bacteriological (biological) warfare could entail, one has only to remember how a natural epidemic may persist unpredictably, and spread far beyond the initial area of incidence, even when the most up-to-date medical resources are used to suppress the outbreak. The difficulties would be considerably increased were deliberate efforts made, for military reasons, to propagate pathogenic organisms. Mass disease, following an attack, especially of civilian populations, could be expected not only because of the lack of timely warning of the danger but because effective measures of protection or treatment simply do not exist or cannot be provided on an adequate scale.

13. Once the door was opened to this kind of warfare, escalation would in all likelihood occur, and no one could say where the process would end. Thus the report concludes that the existence of chemical and bacteriological (biological) weapons contributes to international tension and that their further development spurs the arms race without contributing to the security of any nation.

14. The present report, in accordance with resolution 2454 A (XXIII), will be submitted to the Eighteen-Nation Committee on Disarmament, to the Security Council and to the General Assembly at its twenty-fourth session. We hope that it will contribute to the implementation of measures which, in the final analysis, will eliminate chemical and bacteriological (biological) weapons from all military arsenals.

Chapter I

THE BASIC CHARACTERISTICS OF CHEMICAL AND BACTERIOLOGICAL (BIOLOGICAL) MEANS OF WARFARE

15. Since World War I, when chemical warfare was first resorted to on a large scale, the variety and potency of chemical and bacteriological (biological) weapons has grown steadily, and there has been a corresponding increase in the capacity to deliver them to a target area. The particular threat posed by chemical weapons today derives from the existence of new, and far more toxic, chemical compounds than were known fifty years ago. Since bacteriological (biological) agents exist naturally, their increased potency as weapons has resulted from a process of selection rather than from the production of entirely new agents. As is explained in later sections of this report, selection has been made possible by advances in our knowledge of the genetics of microbes and by advances in experimental aerobiology.

16. The most significant result of these technical developments is the great variety of injurious effect which these agents can induce and the consequent increase in the number and types of situation in which there might be a temptation to use them for military purposes.

A. Characteristics of chemical and bacteriological (biological) weapons

17. For the purposes of this report, chemical agents of warfare are taken to be chemical substances, whether gaseous, liquid, or solid, which might be employed because of their direct toxic effects on man, animals and plants. Bacteriological (biological) agents of warfare are living organisms, whatever their nature, or infective material derived from them, which are intended to cause disease or death in man, animals or plants, and which depend for their effects on their ability to multiply in the person, animal or plant attacked.

18. Various living organisms (e.g., rickettsiae, viruses and fungi), as well as bacteria, can be used as weapons. In the context of warfare all these are generally recognized as "bacteriological weapons". But in order to eliminate any possible ambiguity, the phrase "bacteriological (biological) weapons" has been used throughout to comprehend all forms of biological warfare.

19. All biological processes depend upon chemical or physico-chemical reactions, and what may be regarded today as a biological agent could, tomorrow, as knowledge advances, be treated as chemical. Because they themselves do not multiply, toxins, which are produced by living organisms, are treated in this report as chemical substances. We also recognize that there is a dividing line between chemical agents of warfare, in the sense in which we use the terms, and incendiary substances, such as napalm and smoke, which exercise their effects through fire, temporary deprivation of air or reduced visibility. We regard the latter as weapons which are better classified with high explosives than with the substances with which we are concerned. They are therefore not dealt with further in this report.

20. Finally, we recognize that both chemical and bacteriological (biological) agents are designated either as lethal agents, that is to say, agents which are intended to kill, or as incapacitating agents, that is to say, agents which are intended to cause disability. These terms are not absolute but imply statistical probabilities of response which are more uncertain with bacteriological (biological) than with chemical agents. Not all individuals will die from an attack with a given lethal agent, whereas some, for example, infants and people weakened by malnutrition, disease or old age, as well as a high proportion of individuals in special circumstances, for example, following irradiation, might succumb to an attack with incapacitating chemical or bacteriological (biological) agents. With a few chemical agents, notably some tear gases (lachrymators), there is a negligible probability of any fatal outcome, and these have been used by many Governments to quell riots and civil disorders. When used in this way they are called riot-control agents. Lachrymators have also been widely used in warfare as harassing agents, in order to enhance the effectiveness of conventional weapons or to facilitate the capture of enemy personnel.

1. Differences between chemical and bacteriological (biological) warfare

21. Although there are some similarities between chemical and bacteriological (biological) agents regarded as weapons of war, they differ in certain important respects. These differences are related to (*a*) potential toxicity, (*b*) speed of action, (*c*) duration of effect, (*d*) specificity, (*e*) controllability and (*f*) residual effects.

Potential toxicity

22. Although more toxic than most well-known industrial chemicals, chemical warfare agents are far less potent on a weight-for-weight basis than are bacteriological (biological) agents. The dose of a chemical agent required to produce untoward effects in man is measured in milligrammes,[1] except for toxins which may be in the microgramme

[1] One milligramme equals 1/1,000 of a gramme.

range.[2] The corresponding dose for bacteriological (biological) agents is in the picogramme range.[3]

23. This difference reflects the fact that bacteriological (biological) agents, being alive, can multiply, and its significance is that, weight-for-weight, bacteriological (biological) weapons could be expected to inflict casualties over very much more extensive areas than could chemical weapons.

24. Being living organisms, bacteriological (biological) agents are also very much more susceptible to sunlight, temperature and other environmental factors than are chemical agents. A bacteriological (biological) agent disseminated into a given environment may retain its viability (ability to live and multiply) while losing its virulence (ability to produce disease and injury).

Speed of action

25. As a class, chemical agents produce their injurious effects in man, animals or plants more rapidly than do bacteriological (biological) agents. The time between exposure and significant effect may be minutes, or even seconds, for highly toxic gases or irritating vapours. Blister agents take a few hours to produce injury. Most chemicals used against crops elicit no noticeable effect until a few days have elapsed. On the other hand, a bacteriological (biological) agent must multiply in the body of the victim before disease (or injury) supervenes; this is the familiar "incubation period" of a disease, the time which elapses between exposure to infection and the appearance of symptoms of illness. This period is rarely as short as one or two days and may be as long as a few weeks or even longer. For both chemical and bacteriological (biological) agents the speed of action is affected by the dose (i.e., the quantity absorbed), but this secondary factor does not obscure the basic difference between the two classes of agents in the time they take to manifest their effects.

Duration of effect

26. The effects of most chemical agents which do not kill quickly do not last long, except in the case of some agents, such as phosgene and mustard, where they might continue for some weeks, months or longer. On the other hand, bacteriological (biological) agents which are not quickly lethal cause illness lasting days or even weeks and, on occasion, involve periods of prolonged convalescence. The effects of agents which act against plants and trees would last for weeks or months and, depending on the agent and the species of vegetation attacked, could result in death.

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[2] One microgramme equals 1/1,000 of a milligramme.

[3] One picogramme equals 1/1,000,000 of a microgramme.

Specificity

27. Although both classes of agents can be used to attack man, animals or plants, individual biological agents, in general have a much greater degree of host specificity. Influenza, for example, is essentially a disease of man; foot-and-mouth disease mainly affects cloven-hoofed animals; and rice blast is a disease confined to rice only. On the other hand, some diseases (for example, brucellosis and anthrax) occur both in man and animals. However, chemical agents are much less specific: nerve agents can affect mammals, birds and invertebrates (e.g., insects).

Controllability

28. By controllability is meant the ability to predict the extent and nature of the damage which chemical and bacteriological (biological) agents can cause. This is a most important consideration in their use as weapons. The most likely means of delivering chemical and bacteriological (biological) agents is by discharge into the atmosphere, relying on turbulent diffusion and wind currents to dilute and spread the agent over the area being attacked. Control is thus possible only to the extent that the meteorological situation can be predicted.

29. Because they infect living organisms, some bacteriological (biological) agents can be carried by travellers, migratory birds or animals to localities far from the area originally attacked.

30. The possibility of this kind of spread does not apply to chemical agents. But control of contamination by persistent chemical agents could be very difficult. Should large quantities of chemical agents penetrate the soil and reach underground waters, or should they contaminate reservoirs, they might spread hundreds of kilometres from the area of attack, affecting people remote from the zone of military operations. Although we know of no comparable substance likely to be used as a chemical warfare agent, the spread of DDT over the globe illustrates, in an extreme form, how man-made chemicals can spread. This chemical insecticide is now found in the tissues of creatures in all parts of the world, even in places in which it has never been used. For example, as a result of its transfer through food chains, it is found even in the tissues of the penguins which live in Antarctica.

Residual effects

31. In circumstances which favour their persistence herbicides, defoliants and perhaps some other chemical agents might linger for months, stunting the growth of surviving or subsequent plant life and even changing the floral pattern through selection. Following repeated use, certain chemical agents could even influence soil structure. The risk of residual effects with some bacteriological (biological) agents is potentially greater, mainly because they could lead to disease, which might become epidemic if man-to-man transmission occurred readily.

Bacteriological (biological) agents might also find unintended hosts in the animals and plants of an area or be transported by infected individuals over great distances to new environments.

2. Technology of chemical and bacteriological (biological) warfare

32. The technological problems associated with chemical and bacteriological (biological) warfare are of two kinds: (*a*) those associated with the production of the agents and the weapons needed for their dissemination and (*b*) those which concern the provision of the protective equipment and defences necessary to protect military forces and civilian populations. Any nation whose chemical, pharmaceutical and fermentation industries are well advanced could produce chemical and bacteriological (biological) agents on a scale commensurate with its other military capabilities. The assurance of safety in the production of bacteriological (biological) agents, problems associated with the synthesis of complex chemical agents and deciding on the best weapons to disseminate them are examples of some of the relevant technological difficulties. A special problem associated with the development and maintenance of an offensive capability in bacteriological (biological) warfare relates to the fact that some agents are viable for only a short time (a few days) after manufacture. This period can be extended by refrigeration of the agent or by freeze-drying it before storage. The drying processes, however, are very complex and difficult where large quantities of highly pathogenic agents are involved. The problems which relate to defence are far more difficult, for as with most weapons, effective defence calls for much more stringent training and demands far more manpower and monetary resources than does the offence. For example, alarm systems against chemical attack are very complex electro-mechanical devices whose production demands a highly technologically based industry. They cannot be maintained except by expert and highly trained personnel.

3. Chemical and bacteriological (biological) weapon systems

33. The use in warfare, and the possible military effectiveness, of chemical and bacteriological (biological) agents cannot be appreciated if they are thought of simply as poisons and plagues. They need to be considered in the context of the weapon systems of which they would be part.

34. A weapon system comprises all the equipment and personnel, as well as the organizational structure, required to maintain and operate a military device. By itself, for example, a cannon is not a weapon system. Only when it is integrated into an artillery battery, together with trained crew, ammunition, vehicles, supplies, spare parts, firing table, forward observer, communications and command organization, does it constitute a weapon system. Correspondingly, artillery shells

filled with mustard gas or nerve agents and guns to fire them, or an aircraft with a spray tank filled with a bacteriological (biological) agent, are not by themselves weapon systems.

35. Many complex technological problems have to be overcome in transforming a chemical or bacteriological (biological) "agent" into a "weapon system". A "weapon" is of little military value if it is not dependable and if it cannot be delivered to a target with certainty. This means that in the development of a chemical and bacteriological (biological) weapon system it is not only necessary to consider such matters as mass production, storage, transportation, and means of delivery but the limitations on use set by terrain and weather prediction.

36. In addition, considerations affecting defence need to be taken into account. Masks, protective clothing, detection alarms, special medical supplies, augmented logistic facilities and, above all, thoroughly trained military and civilian personnel are necessary parts of chemical and bacteriological (biological) weapon systems. The concept of a fully developed chemical or bacteriological (biological) weapon system is thus exceedingly complex and implies as much technical capability and as high a degree of training as does the operation of any other advanced weapon systems. Although chemical and bacteriological (biological) weapon systems are cheaper and more readily attained than nuclear weapons, and although they may, in some circumstances, be more effective militarily than conventional weapons, they are highly complex systems which call for sizable resources and considerable expertise for their development and operation. But the possibility always exists that by choosing a single agent and a simple means of delivery a nation could equip itself relatively cheaply to attack a limited area with a reasonable chance of success.

B. Concepts of the use of chemical and bacteriological (biological) weapons in war

1. Chemical weapons

37. Chemical weapons could be used within the zone of contact of opposing forces or against military targets, such as airfields, barracks, supply depots, and rail centres well behind the battle-area itself, or against targets which have no immediate connexion with military operations, such as centres of population, farm land and water supplies. The circumstances in which they could be used within a zone of contact are many and varied—for example, to achieve a rapid and surprise advantage against a poorly trained, ill-equipped military force which lacked chemical protective equipment; to overcome troops in dug-outs, foxholes or fortifications, where they would otherwise be protected against fragmenting and high-explosive weapons; to remove foliage, by means of chemical herbicides, so as to improve visibility, to open up lines of fire and to prevent ambush; to create barriers of con-

taminated land on or in the rear of the battlefield to impede or channel movement; or to slow an enemy advance by forcing the enemy to use protective clothing and equipment. Such equipment undoubtedly restricts mobility and impedes normal activities. It is thus highly probable that once one of two well-equipped sides had been attacked with chemical weapons, it would retaliate in kind, in order to force its opponent to suffer the same penalties of restriction. In all such operations civilians who had not fled from the battle-area might become casualties, as they also would if, while not in the battle-zone, vapours or aerosols drifted towards them with the wind, or if they strayed at a later date into areas contaminated with a persistent agent. The risk of civilian casualties would obviously be greater if chemical attacks were made on military targets well in the rear of the zone of contact and would be very serious in the case of attacks on centres of population.

2. Bacteriological (biological) weapons

38. There is no military experience of the use of bacteriological (biological) agents as weapons of war, and the feasibility of using them as such has often been questioned. One issue which has frequently been raised concerns the validity of extrapolations made from laboratory experience to military situations in the field. Some recent investigations under field conditions throw light on this point.

39. In one field trial, zinc cadmium sulfide (a harmless powder) was disseminated in particles two microns[4] in diameter from a ship travelling 16 kilometres off shore. About 200 kilogrammes were disseminated while the ship travelled a distance of 260 kilometres parallel to the coastline. The resulting aerosol travelled at least 750 kilometres and covered an area of over 75,000 square kilometres.

40. This observation provides an indication of the size of area which might be covered by a windborne aerosol, but it does not tell whether the bacteriological (biological) agents which might be spread in an aerosol would still retain the ability to produce disease. All bacteriological (biological) agents lose their virulence or die progressively while travelling in an aerosol, and the distance of effective travel of the cloud would depend on the rate of decay of the particular agent in the particular atmospheric conditions prevailing.

41. Some idea of the relative size of areas which can be covered by bacteriological (biological) and chemical aerosols can be gained from this same experiment. Had the particles that were carried been a bacterial or viral agent, they would not have caused casualties over as large an area as the one covered, because of decay of the agent while in the aerosol state. However, depending on the organism and its degree of hardiness, areas of from 5,000 to 20,000 km^2 could have been effectively attacked, infecting a high proportion of unprotected

[4] One micron equals 1/1,000,000 of a metre.

people in the area. If the same means are applied to a hypothetical chemical attack using the most toxic chemical nerve agent, then about 0.8 kg of agent would have been released per km^2. The downwind hazard from this, in which some casualties might be expected, would not have extended more than one kilometre, and probably less, unless meteorological conditions were extremely favourable (see chapter III). The area covered by such a chemical attack might thus have been from 50 to 150 km^2, as compared with the 5,000 to 20,000 km^2 for the bacteriological (biological) attack.

42. For purposes of sabotage or covert (secret, as in sabotage actions behind enemy lines) operations, small aerosol generators for bacteriological (biological) agents could be built, for example, into fountain pens or cigarette lighters. It is also possible to conceive of the distribution of bacteriological (biological) agents by hand to poison either water supplies or ventilation systems, especially in a situation of breakdown of sanitary facilities due, say, to military mobilization or to a nuclear attack. In addition to producing casualties, such an attack could produce severe panic. If half a kilo of a culture of Salmonella[5] had been added to a reservoir containing 5 million litres of water, and complete mixing had occurred, severe illness or disability would be suffered by anyone drinking 1 decilitre (about 3 ounces) of untreated water.

43. The same degree of poisoning as would be produced by half a kilo of Salmonella culture could be achieved with 5 kilos of botulinum toxin,[6] 7 kilos of staphylococcal enterotoxin[6] or 50 kilos of V-nerve agent, or, in the case of common industrial chemicals, with five tons of sodium fluoroacetate (used as a rodenticide) or ten tons of potassium cyanide.

C. Chemical and bacteriological (biological) agents

1. Chemical agents

44. Chemical agents are usually described in terms of their physiological effects and are characterized as follows:

Agents affecting man and animals

Nerve agents are colourless, odourless, tasteless chemicals of the same family as organophosphorus insecticides. They poison the nervous system and disrupt vital body functions. They constitute the most modern war chemicals known; they kill quickly and are more potent than are any other chemical agents (except toxins).

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[5] *Salmonella*: a group of bacteria, many species of which produce severe intestinal infections, including gastro-enteritis, food poisoning (ptomaine), paratyphoid fever and typhoid fever.

[6] See chapter II.

Blister agents (vesicants) are oily liquids which, in the main, burn and blister the skin within hours after exposure. But they also have general toxic effects. Mustard gas is an example. Blister agents caused more casualties than any other chemical agent used in the First World War.

Choking agents are highly volatile liquids which, when breathed as gases, irritate and severely injure the lungs, causing death from choking. They were introduced in the First World War and are of much lower potency than the nerve agents.

Blood agents are also intended to enter the body through the respiratory tract. They produce death by interfering with the utilization of oxygen by the tissues. They, too, are much less toxic than nerve agents.

Toxins are biologically produced chemical substances which are very highly toxic and may act by ingestion or inhalation.

Tear and harassing gases are sensory irritants which cause a temporary flow of tears, irritation of the skin and respiratory tract and, occasionally, nausea and vomiting. They have been widely used as riot-control agents and also in war.

Psycho-chemicals are drug-like chemicals intended to cause temporary mental disturbances.

Agents affecting plants

Herbicides (defoliants) are agricultural chemicals which poison or dessicate the leaves of plants, causing them to lose their leaves or die. The effectiveness of different chemical warfare agents against man, animals and plants is shown in table I. The various specific chemical agents are listed and described in chapter 2.

Methods of delivery

45. Chemical munitions are designed to fulfil three objectives: (*a*) to provide a container for the agent so that the agent/munition combination can be delivered to its target; (*b*) to attain an effective distribution of agent over the target area; and (*c*) to release the agent in active form. In the case of incapacitating and riot-control agents, it is necessary that the munition itself should not cause injury or death and that it should not start fires. This is particularly important for devices used in the control of riots.

46. The munitions to be used would depend on the method of delivery, the shape and size of the target area and other variables. Ground-to-ground munitions include grenades, shells, rockets and missile war-heads; air-to-ground munitions include large bombs, dispensers, spray tanks and rockets; emplaced munitions include generators and mines.

TABLE 1. CATEGORIES OF CHEMICAL WARFARE AGENTS AND THEIR CHARACTERISTICS

	Physical state at 20°C	*Persistency*	*Main state of aggregation in target*	*Effective route of entry*	*Effective against*
Nerve agents	Liquid	Low to high	Vapour, aerosol, liquid	Lungs, eyes, skin	Man, animals
Blister agents	Liquid, solid	High	Vapour, aerosol, liquid	Lungs, eyes, skin	Man, animals
Choking agents	Liquid	Low	Vapour	Lungs, eyes, skin	Man, animals
Blood agents	Liquid, vapour	Low	Vapour	Lungs	Man, animals
Toxins	Solid	Low	Aerosol, liquid	Lungs, intestinal tract	Man, animals
Tear and harassing gases	Liquid, solid	Low	Vapour, aerosol	Lungs, eyes	Man, animals
Incapacitants	Liquid, solid	Low	Aerosol, liquid	Lungs, skin	Man, animals
Herbicides (defoliants)	Liquid, solid	Low to high	Aerosol, liquid	Foliage and roots	Plants[a]

[a] Some herbicides, particularly those containing organic arsenic, are also toxic for man and animals.

47. *Ground-to-ground munitions.* Small ground-to-ground munitions (grenades, shells and small rockets) function much like their conventional counterparts. Upon impact in the target area, they would either explode or burn and so expel the agent to form a cloud which would diffuse and drift downwind, resulting in an elongated elliptical area within which casualties would occur. This represents a point source of dissemination (chapter II).

48. Small rockets would frequently be fired in "ripples", and artillery shells in salvos, resulting in a group of impacts over the target area. This would constitute an area source of dissemination (chapter II).

49. Large ground-to-ground (as well as aerial munitions and missile war-heads) might carry a number of small submunitions as well as agent in bulk. The parent munition, upon functioning, would disperse the submunitions over the target area. These would then disseminate the agent over a wide area rather than a single point of impact, as in the case of bulk munitions.

50. Another military concept is to use large war-heads filled with several hundred kilos of an agent of low vapour pressure. Such a war-head, burst at a suitable altitude, would produce a shower of droplets, effectively contaminating everything on which it fell. A number of such weapons could be used to assure that the target was covered.

51. *Air-to-ground munitions.* Bombs dropped from aircraft are larger than most shells and, consequently, would result in a higher concentration of the chemical near the point of ground impact. Bombs bursting close to the ground could be used to achieve a wider dissemination of the agent, especially with chemical agents.

52. A dispenser is a container for submunitions, which, after opening, could remain attached to the aircraft. The submunitions could be released simultaneously or in succession.

53. Small rockets or missiles could also be used to deliver chemical agents from aircraft. The pattern of dispersal would be much the same as that produced by ground-to-ground rockets or missiles.

54. *Ground-emplaced munitions.* Ground-emplaced munitions comprise generators and mines. The generator is a tank containing a chemical agent, a source of pressure and a nozzle through which the agent is forced. Generators would be placed upwind of the target and then activated by a suitable device.

55. Chemical mines would be placed in areas of anticipated enemy activity and would be activated by pressure or trip wires.

2. Bacteriological (biological) agents

56. Like chemical agents, bacteriological (biological) agents may also be classified in terms of their intended use, whether designed to

incapacitate or kill human beings, to incapacitate or kill food and draught animals or to destroy food plants and industrial crops.

57. Bacteria, viruses, fungi and a group of microbes known as rickettsiae are by far the most potent agents which could be incorporated into weapon systems. There is no assurance, however, that other living organisms may not in the future become more important as potential agents for warfare.

The selection of agents for use in warfare

58. The bacteriological (biological) agents which could potentially be used in warfare are far fewer than those which cause naturally occurring disease. To be effective for this purpose they should:

(*a*) be able to be produced in quantity;

(*b*) be capable of ready dissemination in the face of adverse environmental factors;

(*c*) be effective regardless of medical counter-measures;

(*d*) be able to cause a large number of casualties (which would imply that any agent chosen would be highly infectious; but whether the agent chosen would also be easily transmissible from man-to-man would depend upon an intent to initiate an epidemic spread).

Agents affecting man

59. All the diseases under consideration occur naturally, and the causative organisms, with few exceptions, are known to scientists throughout the world. Incapacitating agents are those which, in natural outbreaks, cause illness but rarely death. If the natural disease has an applicable mortality, the agent is regarded as a lethal one. However, these agents when used as aerosol weapons might cause more severe disease than occurs naturally.

60. Different populations have varying degrees of resistance to the diseases produced by bacteriological (biological) agents. An infectious disease which might be only mildly incapacitating in one population might prove disastrous to another. For example, when measles was first introduced into the Hawaiian Islands, it caused far more deaths than in the relatively resistant populations of Europe. A bacteriological (biological) weapon which might be intended only to incapacitate could be highly lethal against a population where resistance had been lowered as a result of malnutrition. Conversely, a weapon which was intended to spread a lethal disease might only cause occasional mild illness in people who had been given a protective vaccine or who had become immune as a result of natural infection. The history of epidemiology is rich with surprises.

61. *Viruses* are the smallest forms of life. Most of them can be seen only with the electron microscope and must be grown on living

tissue (tissue cultures, fertile eggs etc.). Genetic manipulation of the whole virus or chemical manipulation of its nucleic acid might be used to acquire strains of higher virulence or greater stability to environmental stresses.

62. *Rickettsiae* are intermediate between the viruses and bacteria. Like the viruses, they grow only in living tissue. Judging by the scientific literature, research into the genetics of rickettsiae has been less intense than into that of viruses and bacteria.

63. *Bacteria* are larger than viruses, ranging in size from 0.3 micron to several microns. They can be easily grown on a large scale employing equipment and processes similar to those used in the fermentation industry; but special skills and experience would be needed to grow them in quantity in the particular state in which they readily cause disease. Although many pathogenic (disease-producing) bacteria are susceptible to antibiotic drugs, antibiotic-resistant strains occur naturally and can be selected or obtained through the use of suitable methods of genetic manipulation. Similarly, it is possible to select strains with increased resistance to inactivation by sunlight and drying.

64. *Fungi* also produce a number of diseases in man, but very few species appear to have any potential in bacteriological (biological) warfare.

65. *Protozoa* are one-celled microscopic organisms which cause several important human diseases, including malaria. Because of their complex life cycles, they, too, appear to have little significance in the present context.

66. Parasitic *worms*, such as hook-worm, and the filarial worms have very complicated life cycles. They cause illness and disability only after long exposure and repeated infection and would be extremely difficult to produce in quantity, to store, to transport or to disseminate in a weapon. Insects are also difficult to conceive of as weapons. Some, such as the mosquito and the tick, are transmitters of disease and, as "vectors", have to be looked upon as having potential military significance. Higher forms of life, such as rodents and reptiles, can be dismissed in the context of the present discussion.

Agents affecting animals

67. Bacteriological (biological) anti-animal agents, such as foot-and-mouth disease and anthrax, would be used primarily to destroy domestic animals, thereby indirectly affecting man by reducing his food supply.

68. Outbreaks of contagious disease in animal populations, known as epizootics, may spread much more readily than do epidemics among human beings. Viral infections are probably more serious for animals than those caused by other classes of micro-organisms.

69. Most of the bacterial diseases of animals which could probably be used in warfare are also transmissible to man. Human beings would be expected to get the disease if they were affected by the attacking aerosol cloud, and occasional individuals might contract the disease from infected animals.

Agents affecting plants

70. The natural occurrence of devastating plant diseases, such as the blight of potatoes in Ireland in 1845, the coffee rust of the 1870s in Ceylon, the chestnut blight of 1904 in the United States of America, and the widespread outbreaks of cereal (especially wheat) rusts today, has suggested that plant pathogens might be used for military purposes. There are four major requirements for the deliberate development of a plant disease into epidemic (epiphytotic) proportions: large amounts of the host plant must be present in the region; the agent should be capable of attacking the particular varieties of host plant that are grown; adequate quantities of the agent must be present; and the environmental conditions within the region should be favourable for the spread of the disease. An epiphytotic cannot develop if any one of the above requirements is not satisfied.

Methods of delivery

71. Bacteriological (biological) agents can, in principle, be loaded into the same type of munitions as can chemical agents. Other than for covert or "special-purpose missions", bacteriological (biological) weapons, if developed for military purposes, would in all probability be delivered by aircraft or by large ballistic missiles. Aircraft (including cruise missiles and drones) could drop a large number of bomblets from high altitude or spray from a low altitude. Because a small amount of agent will cover relatively large areas, bombs would probably be small (1 kilo or less) and dispersed over as wide an area as possible. They could be released from clusters or from dispensers in the manner of chemical weapons, but probably from a higher altitude.

72. An aircraft could establish a line of agent which, as it travelled downwind, would reach the ground as a vast, elongated infective cloud (see chapter II). The effectiveness of such a procedure would be highly dependent on weather conditions, but the larger the area, the larger the weather front involved, the greater the chances that the predicted results would be achieved. A small relative error might, however, involve a country not in the conflict.

73. It is conceivable that bacteriological (biological) weapons, probably bomblets, could be packaged in a ballistic missile. The bomblets could be released at a predetermined altitude to burst at ground level. The effect would be the same as bomblet delivery by aircraft, except that it would be more costly.

74. Unless transmitted by insects, bacteriological (biological) agents have little power to penetrate the intact skin. Infections through

the respiratory tract by means of aerosols is by far the most likely route to be used in warfare.

75. Many naturally occurring diseases (e.g., influenza, tuberculosis) are spread by the aerosol route, and some of them, notably influenza, can generate into large epidemics. When an infected person sneezes, coughs or even speaks, an aerosol is formed which contains particles ranging widely in size. The larger particles are usually of little importance because they fall to the ground. But small particles (3 microns or less in diameter) dry out rapidly in the air and are the most infectious. They may remain suspended in the atmosphere for a long time. Animal experiments have shown that a great many infectious agents (including many which are transmitted otherwise in nature) can be transmitted to animals by aerosols of small particle size. Laboratory accidents and experiments on volunteers have confirmed the effectiveness of the aerosol route of infection for man.

76. If bacteriological (biological) warfare ever occurred, the aerosol technique would thus be the one most likely to be used, simply because the respiratory tract is normally susceptible to infection by many micro-organisms, because of the wide target area which could be covered in a single attack and because ordinary hygienic measures are ineffective in preventing the airborne route of attack. Since the particle size of an aerosol is crucial to its ability to penetrate into the lung (see chapter III for detailed discussion), the method for aerosolizing a bacteriological (biological) agent would have to be controllable, so as to assure the dissemination of a large proportion of particles less than 5 microns in diameter.

77. Aerosols of bacteriological (biological) agents could be formed by three general methods. Agents could be disseminated by explosive means in much the same way as chemical agents. However, the size of the resulting particle is hard to control by this method, and much of the agent may be destroyed by the heat and shock of the exploding munition. Particles could also be formed by using pressure to force a suspension of the organisms through a nozzle. Particle size is determined by the amount of pressure, the size of the discharge orifices, the physical characteristics of the agent and atmospheric conditions. Size control of solid particles (dry form of agent) can be achieved by "presizing" before dissemination. Aerosol particles could also be produced as a spray by releasing the agent in liquid suspension into a high-velocity air stream. This principle can be applied to spray devices for use on high-performance aircraft.

D. Defence of man against chemical and bacteriological (biological) agents

78. A comprehensive defensive system against attacks by chemical or bacteriological (biological) agents would have to provide for detection

and warning, rapid identification of agents, protection of the respiratory tract and skin, decontamination, and medical prophylaxis and treatment. Some aspects of such a system could be dealt with by fairly simple equipment. Others would necessitate highly sophisticated apparatus. But the whole complex would necessitate a very effective organization manned by well-trained personnel. Although military units and small groups of people could be equipped and trained to protect themselves to a significant extent, it would be impracticable for most (if not all) countries to provide comprehensive protection for their entire civil population.

1. Medical protection

Chemical attacks

79. No general prophylactic treatment exists which could protect against chemical attacks. Antidotes (atropine and oximes) to nerve agents are of value if administered within half an hour before or within a very short time after exposure. Atropine is itself toxic, however, and might incapacitate unexposed individuals given large doses. Skin can be protected from the vapours of blister agents by various ointments, but they are not effective against liquid contamination.

Bacteriological (biological) attacks

80. Vaccination is one of the most useful means of protecting people from natural infective disease and the only useful means available for prophylaxis against bacteriological (biological) attacks. The protective value of vaccines against small-pox, yellow fever, diphtheria and other diseases is fully established, although the protection they afford can be overcome if an immunized individual is exposed to a large dose of the infectious agent concerned. It is probable, however, that even those existing vaccines which are effective in preventing natural infectious diseases might afford only limited protection against respiratory infection by an agent disseminated into the air in large amounts by a bacteriological (biological) weapon. Moreover, whole populations could not be vaccinated against all possible diseases. The development, production and administration of so many vaccines would be enormously expensive, and some vaccines might produce undesirable or dangerous reactions in the recipients.

81. This picture is not significantly altered by certain new developments in the field of vaccination: e.g., the use of living bacterial vaccines against tularaemia, brucellosis and plague; or aerosol vaccination, which is particularly relevant to vaccination of large numbers of people. There have been recent advances in the control of virus diseases, but at present none of these is practicable for the protection of large populations against bacteriological (biological) warfare.

82. Prophylaxis against some diseases can also be provided by the administration of specific antisera from the blood of people or animals

previously inoculated with micro-organisms, or products derived from them, to increase the antibody levels (immunity) in their blood. Tetanus antitoxin is used in this manner, and until more effective methods replaced them, such antisera were used for many diseases. It would, however, be impossible to prepare specific antisera against all possible bacteriological (biological) agents and to make them available for large populations.

83. Other possibilities, for example, the use of therapeutic materials before symptoms appear, are equally remote from practical realization. They include immune serum, gammaglobulin or such drugs as antibiotics or sulfonamide drugs. The use of gammaglobulin to prevent, or mitigate the severity of, disease may be useful for individuals known to have been exposed. But inasmuch as gammaglobulin is made by separation from human blood, stocks could never be available except for isolated cases. In theory, chemoprophylaxis (the use of drugs and antibiotics to prevent infection) might also be useful in the short term for small groups operating at especially high risk. But it would only be prudent to assume that the bacteriological (biological) agents which an enemy might use would be those which were resistant to such drugs.

2. Detection and warning

84. The requirement is to detect a cloud of a chemical or a bacteriological (biological) agent in the air sufficiently quickly for masks and protective clothing to be donned before the attack can be effective. Usually the objective would be to try to detect the cloud upward of the target so that all those downwind could be warned. There are also requirements for the detection of ground contamination with chemical agents and for detection equipment to enable those under attack to decide when it would be safe to remove their protective equipment.

Chemical attacks

85. In the First World War it was possible to rely upon odour and colour as the primary means of alerting personnel that a chemical attack had been launched. The newer, more toxic chemical agents cannot be detected in this way. On the other hand, presumptive evidence that such weapons had been used would none the less still be of value as warning. Once an enemy had used chemical weapons, each subsequent attack would necessarily have to be presumed to be a possible chemical attack, and protective measures would have to be instituted immediately. Individuals would have to mask not only in the air attack in which spray was used, or when there was smoke or mist from an unknown source, or a suspicious smell, or when they suffered unexpected symptoms, such as a runny nose, choking and tightness in the chest or disturbed vision, but whenever any bombardment occurred. Because of the uncertainty, however, it would be clearly desirable to devise and provide

a system of instruments which could detect the presence of toxic chemicals at concentrations below those having physiological effects and which would give timely and accurate warning of a chemical attack. It would also be advantageous to have test devices, collectors and analytical laboratory facilities in order to determine whether the environment was safe, as well as to identify accurately the specific chemical agent used in an attack.

86. The first and essential component of a defensive system would be an instrument which could detect low concentrations of a chemical agent. However low the concentration, a person could inhale a toxic amount in a short time because he breathes 10-20 litres of air per minute. Inasmuch as the human body can eliminate or detoxify very small amounts of many toxic materials, there is no need to consider very long periods of exposure—the concern is with the exposures of only a few hours. This is often referred to technically as the Ct (concentration time) factor. Essential requirements of a method of detection suitable for use by military or civil defence personnel are that it be simple, specific, sensitive and reliable. Typical detector kits contain sampling tubes and/or reagent buttons, papers etc. After being exposed to particular chemical agents, these detectors change colour or exhibit some other change easily observable without special instruments. Chemical detection kits could also be used to decide when it is safe to remove protective masks or other items of protective clothing. Obviously, laboratories, whether mobile or fixed, can perform more elaborate chemical analyses than can detection kits.

87. Warning devices which have been devised incorporate sensitive detectors that actuate an automatic alarm which alerts individuals to take protective action before a harmful dose of agent is received. They are of two trends: point sampling devices, which sample the air at one location by means of an air pump, and area-scanning devices, which probe a specific area for chemical agents. The disadvantage of point source alarms is that they must be placed upwind of the area that has to be protected, and a rather large number may be needed. If the wind shifts, they have to be repositioned. Successful area-scanning alarms have not yet been developed.

88. It must be recognized that in spite of instrumental warning systems, personnel near the point of dissemination of a chemical agent might still not have sufficient time to take protective action.

Bacteriological (biological) attacks

89. Unlike chemical weapons, bacteriological (biological) weapons cannot readily be distinguished from the biological "background" of the environment by specific chemical or physical reactions, and much lower aerosol concentrations of bacteriological (biological) agents are dangerous than of chemical agents. The problem of early detection and warning is thus even more difficult than for chemical weapons. A partial

solution to the problem has been achieved with certain non-specific but very sensitive physical devices, such as particle counters and protein detectors (protein is a typical constituent of micro-organisms). Presumptive evidence of a bacteriological (biological) attack might be obtained if there is an unusual deviation from the normal pattern of material in the air recorded by the instruments. The elevation of such a deviation, however, would necessitate intensive and prolonged study of the normal pattern in a given location. This subject is discussed further in annex I.

3. Physical protection

90. The primary objective is to establish a physical barrier between the body and the chemical and bacteriological (biological) agents and, especially, to protect the skin and the respiratory tract. Without this no warning system, however effective, has the slightest value. Protection could be achieved by using various types of individual protective equipment or by means of communal shelters.

Individual protection

91. Protective masks are the first line of defence against all chemical and bacteriological (biological) agents. Although protective masks differ in appearance and design, they have certain features in common: a fitted facepiece, made of an impermeable material soft enough to achieve an effective seal against the face, and some means of holding it in place, such as a headstrap, and a filter and absorption system, in canister or other form, which will remove particulate (aerosol) agents by mechanical filtration. The canister also contains activated charcoal, sometimes impregnated to react with agents in the vapour state, but which in any case will absorb toxic vapours. Some masks are made so as to permit the drinking of water while the individual is masked, or attempts at resuscitation measures on casualties without unmasking them. Civil defence masks are often less elaborate versions of the military mask. Gas-proof protectors can be provided for infants.

92. A protective mask, properly fitted and in good working condition, will provide complete respiratory protection against all known chemical and bacteriological (biological) agents. However, a certain percentage of masked personnel can be expected to become casualties because of lack of training, failure to keep the mask in good condition, growth of beard, facial injuries that prevent a good fit etc. The amount of leakage that can be tolerated with bacteriological (biological) agents is much less because of their greater potency.

93. Since mustard gases and the nerve agents of low or intermediate volatility can penetrate the unbroken skin, even through normal clothing, the whole body surface must be protected by some form of special clothing, of which there are two kinds, one which is impermeable

to liquid agents, and the other which, though permeable to air and moisture, has been treated so as to prevent chemical agents from getting through. Rubber-coated fabrics, made into protective suits, constitute the first. Normal clothing, treated with chlorimides or absorbents, is an example of the second. In addition, some form of impermeable cover, ground sheet or cape, can be used to protect against gross liquid contamination. Feet and hands are usually protected by special gloves and either boot covers or treated boots.

94. Together with a mask, protective clothing, properly worn and in good condition, will afford excellent protection against known chemical and bacteriological (biological) agents. The greatest degree of protection is provided by the impermeable type, but when worn continuously it becomes very burdensome because of heat stress, particularly in warm environments. Permeable clothing allows somewhat greater activity, but even so, physical activity is impaired.

Collective or communal protection

95. Collective protection takes the form of fixed or mobile shelters capable of accommodating groups of people and has been devised not only for civilians but for special groups of military personnel (e.g., command posts, field hospitals). Collective protection is the most effective physical means of protection against all forms of attack. Sealing or insulating the shelter will provide protection only for a limited time because of lack of ventilation. Sealing plus a supply of oxygen and a means of eliminating carbon dioxide is better, but again the time of occupancy is limited. The shelter could none the less be safe even though surrounded by fire or high concentrations of carbon monoxide. The best kind of shelter provides ventilation with filtered air to maintain a positive pressure relative to that outside. This positive internal pressure prevents the penetration of airborne agents and permits entry or exit of personnel and equipment without contamination of the interior of the shelter. Extended periods of occupancy are possible.

96. These principles of collective protection are applicable to all enclosures arranged for human or animal occupancy. They have been used to provide protection by hastily constructed or improvised field shelters, mobile vans and armoured vehicles, and permanent or fixed shelters designated for housing civilian or military personnel.

97. Once a bacteriological (biological) attack had been suspected or detected, it would be necessary to identify the specific agents involved so that proper protective measures could be taken and chemoprophylaxis and treatment planned. Identification would also help to predict the incubation period and hence the time available for remedial measures to be taken. At present the only means of identifying specific micro-organisms is by normal laboratory procedures. Many routine laboratory methods of identification require as long as two to five days, but some recent developments have reduced this time appreciably. It is possible

to collect the particles from large volumes of air and concentrate them in a small amount of fluid. Bacteria can then be trapped on special filters and transferred to nutrient media, where sufficient growth may take place to permit identification of some kinds of bacteria within fifteen hours. Another method, the fluorescent antibody technique, can be highly specific and is applicable to bacteria and some viruses. In some cases, it allows of specific identification within a few hours. But despite all these recent developments, laboratory identification of biological agents is still a complicated and unsatisfactory process.

4. Decontamination

Chemical agents

98. Prolonged exposure to weather and sunlight reduces or eliminates the danger of most chemical agents, which are slowly decomposed by humidity and rain. But one could not rely on natural degradation to eliminate the risk, and, in general, it would be essential to resort to decontamination. This would reduce the hazard, but it is a time-consuming process and would greatly hamper military operations.

99. A wide range of chemicals could be used as decontaminants, the choice depending on the particular agent which has to be neutralized, the type of surface that needs to be treated, the extent of contamination and the amount of time available. Decontaminants range from soap and detergent in water to caustic soda, hypochlorite and various organic solvents, and their successful use calls for large numbers of people, a copious supply of water and appropriate equipment.

100. Decontaminating solutions, powders, applicators and techniques have been developed for decontaminating skin, clothing, personal equipment and water, but they would need to be used immediately after an attack.

101. Unless food had been stored in metal cans or other containers which were impermeable to chemical agents, it would have to be destroyed. Decontamination of complex equipment and vehicles is a difficult and time-consuming procedure. Special pressurized sprayers to disseminate powdered and liquid decontaminants have been developed for this purpose, as have paints or coatings to provide a smooth impermeable surface to preclude the penetration of chemical agents.

102. Decontamination might even need to be extended to roads and selected areas. This would involve the removal of contaminated soil by bulldozing or by covering it with earth, using explosives to spread a powdered decontaminant over a wide area.

Bacteriological (biological) agents

103. Decontamination procedures for biological agents are similar to those used for toxic chemical agnets. Aeration and exposure to strong

sunlight will destroy most micro-organisms, as will exposure to high temperatures. Thoroughly cooking exposed food and boiling water for at least fifteen minutes will kill almost all relevant micro-organisms. Calcium hypochlorite and chlorine can also be used to purify water. Certain chemical compounds, such as formaldehyde, ethylene oxide, calcium and sodium hypochlorites, sodium hydroxide and betapropiolactone, can be used to decontaminate materials and work areas. A hot, soapy shower is the best way to decontaminate human beings.

E. Protection of domestic animals and plants against chemical and bacteriological (biological) attacks

1. Chemical attacks

104. The widespread protection of domestic animals and plants from chemical attack would be impracticable. Once a crop had been attacked with herbicides there is no effective remedial action. The damage could be made good only by a second planting of either the same or another crop, depending on the season.

2. Bacteriological (biological) attacks

Animals

105. Animals or flocks could be protected by collective shelters, although the cost would be great and, in the absence of automatic warning devices, it would be impossible to assure that the creatures would be sheltered at the time of attack.

106. The ideal means of protection for animals would be vaccination. Vaccines have been developed, and many are routinely produced, for foot-and-mouth disease, rinderpest, anthrax, Rift Valley fever, hog cholera, Newcastle disease and others. Vaccination of animal herds by aerosols is a promising area of investigation.

Plants

107. The only hopeful approach would be to breed disease-resistant plants. This is a regular part of most national agricultural programmes and has as its object the increase of crop yields. But unless the exact identity of the bacteriological (biological) agent which might be used were known well in advance (possibly years), it would not be feasible to apply this principle to provide protection to crops against this kind of attack.

108. Efforts devoted to spraying fungicides and similar preparations to reduce loss after attack do not appear to be economically effective. In most cases the best procedure is to utilize available manpower and machines in planting second crops.

Chapter II

THE PROBABLE EFFECTS OF CHEMICAL AND BACTERIOLOGICAL (BIOLOGICAL) WEAPONS ON MILITARY AND CIVILIAN PERSONNEL, BOTH PROTECTED AND UNPROTECTED

A. The effects of chemical agents on individuals and populations

109. The effects of chemical warfare agents on humans, animals and plants depend on the toxic properties of the agent, the dose absorbed, the rate of absorption and the route by which the agent enters the organism. Toxic agents may enter the body through the skin, the eyes, the lungs or the gastro-intestinal tract (as a result of eating contaminated food or drinking contaminated liquids).

110. For a given agent absorbed under the same conditions, the effect will be proportional to the dose absorbed. This is why it is possible to define for each agent certain characteristic doses, such as the dose which, under given conditions, will on average cause death in 50 per cent of the individuals exposed (the 50 per cent lethal dose, or LD 50), or the dose which will cause 50 per cent non-fatal casualties, or the dose which will have no appreciable military effect. These are expressed in milligrammes of agent, with reference to a healthy adult of average weight. They may also be given in terms of milligrammes per kilogramme of body weight.

111. For purposes of evaluation it is convenient to express the same idea somewhat differently in the case of gases, vapours and aerosols absorbed through the respiratory passages. Here the absorbed dose depends on the concentration of the agent in the air, on the respiration rate of the subject and on the duration of the exposure. If, for the sake of illustration, it is assumed that the average respiration rate for groups of individuals engaged in various activities remains relatively constant, it follows that the dose, and therefore the effect produced, will be directly proportional to the product of the concentration of the agent in the air (C in milligrammes/cubic metre) and the exposure time (t in minutes). This is called the dosage (or Ct factor), certain characteristic values of which (for example, the LD 50) are used in particular situations for quantitative estimates of the effects produced.

112. For toxic agents acting on or through the skin, the dose absorbed by contact will often be related to the "contamination rate",

expressed in grammes/square metre, which indicates to what extent surfaces are contaminated by the liquid.

113. The consequences of an attack on a population are a combination of the effects on the individuals in it, with both the concentration of agent and the susceptibility of individuals varying over the whole area exposed to risk. Different individuals would respond differently to an attack and might have different degrees of protection. Possible long-term contamination of personnel from chemical warfare agents persisting on the ground and vegetation may add to the immediate, direct effects.

114. Protective masks, protective clothing and shelters and, to a certain extent, decontamination when applicable, give substantial protection against all chemical warfare agents. But, as already emphasized, the mere possession of a means of protection by no means constitutes an absolute safeguard against contamination by poisons. Alarm and detection equipment is important, sometimes vital, because without it timely warning, which is essential to the proper use of protective equipment, would be lacking. Since protective measures are most effective when performed by trained personnel working in units, military personnel are more likely to be provided with adequate protection than a civilian population. In any event, the civilian population in most countries is simply not provided with protection against chemical warfare.

115. Several chemical warfare agents which were known during the First World War, and others developed since, have been reported on in the scientific literature. However, the effects of the more lethal modern chemical weapons have not been studied under conditions of actual warfare. Furthermore, no complete and systematic field studies of the use of defoliants, herbicides and riot-control agents are available. The following descriptions of the probable effects of chemical weapons, based both on evidence and on technical judgement, must therefore be regarded as somewhat conjectural.

1. Effects of lethal chemical agents on individuals

116. Table 2 provides a classification of the most important lethal chemical agents and notes some of their characteristics in terms of the effects they produce. More details are given in annex II.

117. Lethal chemical agents kill in relatively small doses, and as a rule the amount that causes death is only slightly greater than that which causes incapacitation. Death may occasionally be caused by high doses of presumed incapacitating agents, and, conversely, minor effects could be caused by low doses of lethal agents. Blister agents are considered with the lethal agents, inasmuch as a small but significant fraction of the personnel attacked with such agents may die or suffer serious injury.

TABLE 2. GENERAL CHARACTERISTICS OF LETHAL CHEMICAL AGENTS

Type	*Mechanism*	*Time for onset of effects*	*Examples*
Nerve agent G	Interferes with transmission of nerve impulses	Very rapid by inhalation (a few seconds)	Tabun, Sarin, Soman
Nerve agent V	Interferes with transmission of nerve impulses	Very rapid by inhalation (a few seconds); relatively rapid through skin (a few minutes to a few hours)	VX
Blister agent	Cell poison	Blistering delayed hours to days; eye effects more rapid	Sulphur mustard Nitrogen mustard
Choking agent	Damages lungs	Immediate to more than three hours	Phosgene
Blood agent	Interferes with all respiration	Rapid (a few seconds or minutes)	Hydrogene cyanide
Toxin	Neuromuscular paralysis	Variable (hours or days)	Botulinum toxin

Nerve agents

118. These lethal compounds are readily absorbed through the lungs, eyes, skin and intestinal tract without producing local irritation, and they interfere with the action of an enzyme (cholinesterase) essential to the functioning of the nervous system. The nerve-agent casualty who has been exposed to a lethal dose will die of asphyxiation within a few minutes if he is not treated swiftly by means of artificial respiration and drugs, such as atropine or oximes. Otherwise recovery is generally rapid and complete. Occasionally, it may take several weeks but will be complete unless anoxia or convulsions at the time of exposure were so prolonged as to cause irreversible brain damage.

119. The route of entry of the agent into the body has some influence on the appearance of symptoms. These develop more slowly when the agent is absorbed through the skin than when it is inhaled. Low dosages cause a running nose, contraction of the pupil of the eye and difficulty in visual accommodation. Constriction of the bronchi causes a feeling of pressure in the chest. At higher dosages, the skeletal muscles are affected, weakness, fibrillation and, eventually, paralysis of the respiratory muscles occurring. Death is usually caused by respiratory failure, but heart failure may occur. It is estimated that the most toxic nerve gases may cause death at a dosage of about 10 mg min/m^3.[7] Less toxic ones are lethal at dosages of up to 400 mg min/m^3.

[7] A dosage of one mg min/m^3 consists of an exposure for one minute to gas at a concentration of one milligramme per cubic metre.

Blister agents or vesicants

120. Mustard is a typical blister agent which, like other members of this class, also has general toxic effects. Exposure to concentrations of a few mg/m^3 in the air for several hours results at least in irritation and reddening of the skin and, especially, irritation of the eyes and may even lead to temporary blindness. Exposure to higher concentrations in the air causes blisters and swollen eyes. Severe effects of this kind also occur when liquid falls on the skin or into the eyes. Blistering with mustard is comparable to second-degree burns. More severe lesions, comparable to third-degree burns, may last for a couple of months. Blindness may be caused, especially if liquid agent has entered the eyes. Inhalation of vapour or aerosol causes irritation and pain in the upper respiratory tract, and pneumonia may supervene. High doses of blister agents cause a general intoxication, similar to radiation sickness, which may prove lethal.

121. The first step in treating a person who has been exposed to a vesicant or blister agent, is to wash it out of the eyes and decontaminate the skin. Mild lesions of the eyes require little treatment. The blisters are treated in the same way as any kind of second-degree burn.

Other lethal agents

122. *Phosgene* and compounds with similar physiological effects were used in the First World War. Death results from damage to the lungs. The only treatment is inhalation of oxygen and rest. Sedation is used sparingly.

123. *Hydrogen cyanide* in lethal doses causes almost immediate death by inhibiting cell respiration. Lower doses have little or no effect.

124. Most of the so-called blood agents contain cyanide, and all act rapidly. The casualty would either die before therapy could begin or recover soon after breathing fresh air.

125. *Botulinum toxin* is one of the most powerful natural poisons known and could be used as a chemical warfare agent. There are at least six distinct types, of which four are known to be toxic to man. Formed by the bacterium *Clostridium botulinum*, the toxin is on occasion accidentally transmitted by contaminated food. The bacteria do not grow or reproduce in the body, and poisoning is due entirely to the toxin ingested. It is possible that it could be introduced into the body by inhalation.

126. Botulism is a highly fatal poisoning characterized by general weakness, headache, dizziness, double vision, dilation of the pupils, paralysis of the muscles concerned in swallowing and difficulty of speech. Respiratory paralysis is the usual cause of death. After consumption of contaminated food, symptoms usually appear within twelve to seventy-two hours. All persons are susceptible to botulinum poisoning. The few

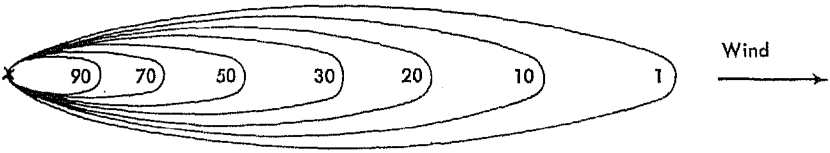
who recover from the disease develop an active immunity of uncertain duration and degree. Active immunization with botulinum toxoid has been shown to have some protective value, but antitoxin therapy is of limited value, particularly where large doses of the toxin have been consumed. Treatment is mainly supportive.

2. Effects of lethal agents on populations

127. As already indicated, the possible effects of an attack on populations with lethal chemical warfare agents would depend upon the agent used, upon the intensity of the attack, whether the population was mainly under cover or in the open, on the availability of protective facilities, on the physiological state of the individuals affected and on the meteorological conditions, which might differ from what had been predicted and alter during the course of an attack.

128. The importance of meteorological conditions on the spread of an agent from its point or area of release is illustrated by Figures I, II and III, which show in an idealized diagrammatic form the type of dosage contours to be expected from a point source, from multiple sources and from a linear aerial source, respectively, when exposed to the effects of wind.

Figure I. Shape of the zone covered by a wind-blown cloud in the case of a point source on the ground



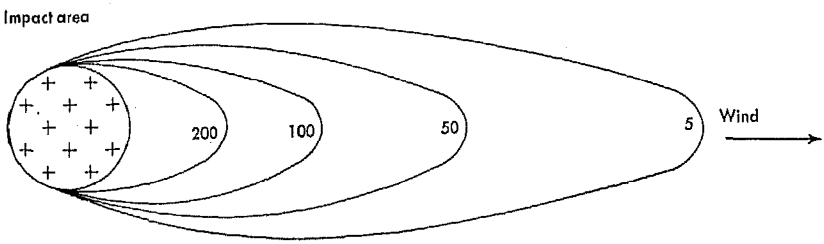
129. Figure I shows the shape of the zone travelled by the chemical cloud produced by a point source (for example, one isolated munition), at the far left of the innermost cigar-shaped figure under conditions of a strong wind (say, 5-20 km/h) in the direction indicated.

130. The number on each line indicates the dosage (Ct = concentration time) on the line. The dosage at any point inside the area delimited by the curve is greater than the number indicated. On the basis of these data, it is possible to estimate the casualties when the characteristic dosages of the agent used are known. For example, if the LD 50 value of the agent were 30 milligramme-minutes/cubic metre, there would be more than 50 per cent fatalities in the area inside the contour marked 30.

131. This figure applies to a volatile agent, such as Sarin, which is usually released in the form of a vapour or an aerosol cloud. In the

case of a non-volatile liquid released in the form of droplets which fall onto the ground and contaminate it, a corresponding map could be drawn for the level of contamination of the soil (expressed in milligrammes/ square metre).

FIGURE II. SHAPE OF THE ZONE COVERED IN THE CASE OF MULTIPLE SOURCES (AREA SOURCE)

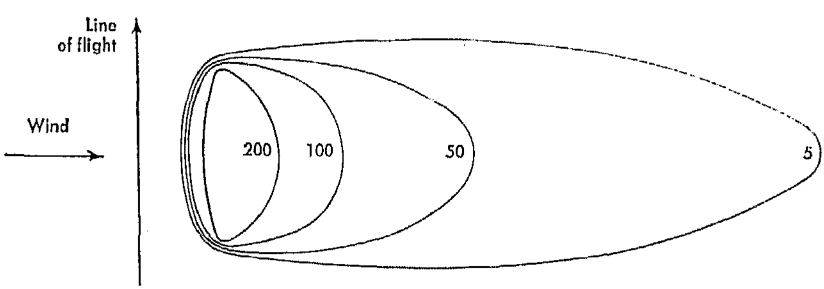


132. Figure II shows the same phenomenon in relation to an area source such as would result, for example, from attack by a missile warhead filled with small bombs or by an artillery salvo.

133. In the case of a volatile agent released in the form of a vapour or aerosol, the resulting cloud, carried downwind, covers a zone whose general shape is the same as in the case of a point source (Figure I) but its dimensions are obviously much larger, and the dosage values are also larger.

134. If a non-volatile agent were released in the form of droplets, the hazard would be very great in the impact area because all surfaces (skin, clothing, vehicles, equipment, vegetation etc.) would be contaminated. The downwind hazard caused by the drift of the most minute particles would extend over a much smaller area than in the previous case because only a relatively small number of minute particles would be carried by the wind.

FIGURE III. SHAPE OF THE ZONE COVERED IN THE CASE OF A LINEAR AERIAL SOURCE



135. Figure III shows the zone covered by a linear aerial source, as in the case of dissemination of a non-volatile agent from an aircraft.

136. The emitted cloud is carried by the wind and does not touch the ground until it has travelled some distance away from the line of flight of the disseminating aircraft; this depends on the altitude of the aircraft and on the wind velocity. Since the cloud has already been subjected to the influence of turbulent diffusion before reaching the ground, the dosage values or contamination rates will be highest some distance away from the zone boundary nearer the source.

137. Because of meteorological and other variables, it is impossible to make general statements about the quantitative effects of chemical weapons on populations. The following hypothetical examples, therefore, are intended merely to illustrate what might happen and the degree to which protective measures could reduce casualties. To provide representative illustrations, the examples chosen include the different hazards created by nerve agents used in a battle zone, on military targets in the rear and on civilians in a town.

Effects of nerve gas on protected troops in combat

138. A heavy attack with air-burst munitions dispersing non-volatile liquid nerve agent would create concentrations on the ground that could range from one tenth of a gramme to ten grammes of liquid per square metre, giving a mean value of about five grammes. This would be extremely hazardous. At the same time, aerosol concentrations would be created over almost the entire impact area (dosages about 20 mg. min/m^3). This would produce casualties even if there were no liquid hazard.

139. To counter this type of attack, protective measures of a very high order of efficiency, including protective masks, light protective clothing, means for decontamination, detection systems, antidotes and medical care, would have to be available. Protective clothing and rapid utilization of gas masks would give a certain measure of protection. But in this case, subsequent decontamination and medical care would be necessary to avoid heavy lethal losses.

Effects of nerve gas on a military target in the rear

140. An attack from the air with a volatile nerve agent against a military installation in a rear area would cause an intense liquid and vapour hazard in the installation itself and a vapour hazard downwind in the surrounding area. As suggested in figure II, the impact area would be very heavily contaminated; gas dosages inside and close to the impact area would be very high. Further downwind the gas concentration would decrease gradually and finally become innocuous. A general picture of the way casualties would occur in a downwind area is indicated in figure I.

141. After an attack in which tons of Sarin were used against an area of one square kilometre, the impact area and the area immediately

downwind from it would be highly lethal to all unprotected personnel. Lethal casualties would occur at dosages above 80 mg. min/m^3 and servere casualties down to 30 mg. min/m^3. Some very light casualties would result at dosages around 5 mg. min/m^3. The distance between the impact area and the area of lowest effective dosage would depend on the local topography and on weather conditions but would rarely exceed a few tens of kilometres.

142. Personnel provided only with gas masks, but not wearing them at the moment of the attack, would suffer substantial losses in and close to the impact area, both because of the effects of the liquid and because of the high gas concentration inhaled before they could don their masks. Further downwind, masks would give essentially complete protection if warning were provided reasonably quickly.

Effects of a nerve gas attack on a town

143. The population density in a modern city may be 5,000 people per square kilometre. A heavy surprise attack with non-volatile nerve gas by bombs exploding on impact in a wholly unprepared town would, especially at rush hours, cause heavy losses. Half of the population might become casualties, half of them fatal, if about one ton of agent were disseminated per square kilometre.

144. If such a city were prepared for attack, and if the preparations included a civil defence organization with adequately equipped shelters and protective masks for the population, the losses might be reduced to one half of those which would be anticipated in conditions of total surprise.

145. Although it would be very difficult to achieve, if there were a high level of preparedness, comprising adequate warning and effective civil defence procedures, it is conceivable that most of the population would be sheltered at the time of the attack and that very few would be in the streets.

146. Given a town with a total population of 80,000, a surprise attack with nerve gas could thus cause 40,000 casualties, half of them fatal, whereas under ideal circumstances for the defence, fatalities might number no more than 2,000. It is inconceivable, however, that the ideal would ever be attained.

3. Effects of incapacitating chemical agents

147. Incapacitating chemicals, like tear gases and certain psychochemicals, produce in normal healthy people a temporary, reversible disability with few, if any, permanent effects. In young children, old people and those with impaired health, the effects may sometimes be aggravated. They are called incapacitating because the ratio between the lethal and incapacitating doses is very high. The types which could

have a possible military use are limited by requirements of safety, controlled military effectiveness and economic availability.

Tear and harassing gases

148. Many chemical compounds fall into this category, of which ω-chloracetophenone (CN), ortho-chlorobenzylidenemalononitrile (CS) and adamsite (DM) are probably the most important. They are solids when pure and are disseminated as aerosols.

149. Either as vapour or in aerosol, tear and harassing gases rapidly produce irritation, smarting and tears. These symptoms disappear quickly after exposure ceases. The entire respiratory tract may also be irritated, resulting in a running nose and pain in the nose and throat. More severe exposures can produce a burning sensation in the trachea. As a result, exposed persons experience difficulty in breathing, attacks of coughing and, occasionally, nausea and headaches.

150. Extremely high dosages of tear and harassing gases can give rise to pulmonary edema (fluid in the lungs). Deaths have been reported in three cases after extraordinary exposure to ω-chloracetophenone (CN) in a confined space.

151. The effects of adamsite (DM) are more persistent. Nausea is more severe, and vomiting may occur.

152. Results of experiments on various species of animals (see annex III) and some observations of human responses lead to the following tentative conclusions. First, CS is the most irritating of these gases, followed by adamsite (DM) and ω-chloracetophenone (CN). Second, the tolerance limits (highest concentration which a test subject can tolerate for one minute) of DM and CS are about the same. Third, the least toxic of the tear gases is CS, followed by DM and then CN. Fourth, human beings vary in their sensitivity to, and tolerance of, tear and harassing gases. And, finally, the toxicity of these gases varies in different animal species and in different environmental conditions.

153. The symptoms caused by tear gases disappear, as tears wash the agent from the eyes, and if the victim gets out of the tear gas atmosphere. Some tear gases, however, cause reddening or, rarely, even blistering of the skin when the weather is hot and wet.

Toxins

154. Staphylococcus toxin occurs naturally in outbreaks of food poisoning, which is the only medical experience with this toxin. The symptoms have a sudden, sometimes violent, onset, with severe nausea, vomiting and diarrhea. The time from ingestion of the toxin to the onset of symptoms is usually two to four hours, although it may be as short as half an hour. Most people recover in 24-48 hours, and death is rare. Treatment is supportive, and immunity, following an attack, is

short-lived. The toxin is resistant to freezing, to boiling for thirty minutes and to concentrations of chlorine used in the treatment of water. Staphylococcus toxin could be considered as an incapacitating chemical warfare agent. Symptoms can be produced in animals by intravenous injection, and the toxin may also be active by the respiratory route.

Psychochemicals

155. These substances have been suggested for use in war as agents which could cause temporary disability by disrupting normal patterns of behaviour. The idea cannot be accepted in its simple form, inasmuch as these substances may lead to more permanent changes, particularly in individuals who are mentally unbalanced or in the early stages of a nervous or mental disease. Moreover, very high doses, which would be difficult to exclude during use in war, can cause irreversible damage to the central nervous system or even death. Psychochemicals could also have particularly severe effects on children.

156. Compounds such as LSD, mescaline, psilocybin and a series of benzilates which cuase mental disturbance—either stimulation, depression or hallucination—could be used as incapacitating agents. Mental disturbance, of course, is a very complex phenomenon, and the psychological state of the person exposed to a psychochemical, as well as the properties of the agent, would profoundly influence its manifestations. But, despite the variation in responses between individuals, all those affected could not be expected to act rationally or to take the initiative to make logical decisions.

157. Psychochemicals do more than cause mental disturbance. For example, the general symptoms from the benzilates are interference with ordinary activity; dry, flushed skin; irregular heartbeat; urinary retention; constipation; slowing of mental and psychical activity; headache; giddiness; disorientation; hallucinations; drowsiness; occasional maniacal behaviour; and increase in body temperature. Although these effects have not been fully studied, there would be a significant risk of affected individuals, particularly military personnel, becoming secondary casualties because of unco-ordinated behaviour. A single dose of 0.1 to 0.2 mg LSD25 will produce profound mental disturbance within half an hour, the condition persisting for about ten hours. This dose is about a thousandth of the lethal dose.

158. Treatment of the symptoms of psychochemicals is mainly supportive. Permanent psychotic effects may occur in a very small proportion of individuals exposed to LSD.

159. It is extremely difficult to predict the effects which an attack with psychochemical agents would produce in a large population. Apart from the complication of the varying reaction of exposed individuals, there could be strange interactions within groups. A few affected individuals might stimulate their fellows to behave irrationally; in the

same way as unaffected persons might to some extent offset the reactions of those affected. Inasmuch as the probability of fatal casualties resulting directly from exposure is low, some normal group activity might be sustained. Protective masks would probably provide complete protection, inasmuch as practically all potential psychochemical agents, if used as offensive weapons, would be disseminated as aerosols.

4. Other effects of chemical agents

Effects on animals

160. The effects of lethal chemical agents on higher animals are, in general, similar to those on man. The nerve agents also kill insects.

Effects on plants

161. A variety of chemicals kill plants, but, as already indicated, little is known about their long-term effects. The effective dose ranges of defoliants vary according to the particular species of plant attacked, its age, the meteorological conditions and the desired effect: e.g., plant death or defoliation. The duration of effect usually lasts weeks or months. Some chemicals kill all plants indiscriminately; others are selective. Most defoliants produce their effects within a few weeks, although a few species of plant are so sensitive that defoliation would occur in a period of days.

162. An application of defoliating herbicide[8] of approximately 3 gallons (32 pounds) per acre (roughly 36 kg per hectare) can produce 65 per cent defoliation for six to nine months in very densely forested areas, but in some circumstances some species of trees will die. Significantly lower doses suffice for most agricultural and industrial uses throughout the world. Defoliation is, of course, a natural process —more common in trees in temperate zones than in the tropics. Essentially what defoliants do is trigger defoliation prematurely.

163. Desiccation (the drying out) of leaves results in some defoliation, although usually the leaf drop is delayed, and the plant would not be killed without repeated application of the chemical. Chemical desiccants cause a rapid change in colour, usually within a few hours.

B. The effects of bacteriological (biological) agents on individuals and populations

164. Mankind has been spared any experience of modern bacteriological (biological) warfare, so that any discussion of its possible nature has to be based on extrapolation from epidemiological knowledge

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[8] For example, the commonly used "2,4-D" and "2,4,5-T", which are the butyl esters of (2,4-dichlorophenoxy) acetic acid and (2,4,5-trichlorophenoxy) acetic acid.

and laboratory experiment. The number of agents which potentially could be used in warfare is limited by the constraints detailed in chapter I. On the other hand, the variability which characterizes all living matter makes it conceivable that the application of modern knowledge of genetic processes and of selection could remove some of these limitations. Some species of micro-organisms consist of a number of strains characterized by different degrees of virulence, antigenic constitution, susceptibility to chemotherapeutic agents and so on. For example, strains of tularaemia bacilli isolated in the United States are generally much more virulent in human beings than those found in Europe or Japan. Foot-and-mouth disease virus is another well-known example of an organism with various degrees of virulence. The situation with bacteriological (biological) weapons is thus quite different from that of chemical weapons, where the characteristics of a given compound are more specific.

1. Effects on individuals

165. Bacteriological (biological) agents could be used with the intention of killing people or of incapacitating them either for a short or a long period. The agents, however, cannot be rigidly defined as either lethal or incapacitating, inasmuch as their effects are dependent upon many factors relating not only to themselves but to the individuals they attack. Any disease-producing agent intended to incapacitate may, under certain conditions, bring about a fatal disease. Similarly, attacks which might be intended to provoke lethal effects might fail to do so. Examples of naturally occurring lethal disease are shown in table 3 and representative incapacitating diseases in table 4. A detailed list of possible agents, with a brief description of their salient characteristics is given in annex IV.

166. A number of natural diseases of man and domestic animals are caused by mixed infections (e.g., swine influenza, hog cholera). The possible use of two or more different organisms in combination in bacteriological (biological) warfare needs to be treated seriously because the resulting diseases might be aggravated or prolonged. In some instances, however, two agents might interfere with one another and reduce the severity of the illness they might cause separately.

167. The effects of some forms of bacteriological (biological) warfare can be mitigated by chemotherapeutic, chemoprophylactic and immunization measures (for protection see chapter I and annex IV). Specific chemotherapeutic measures are effective against certain diseases but not against those caused by viruses. However, it may not always be possible to apply such measures, and they might not always be successful. For example, with some diseases early therapy with antibiotics is usually successful but relapses may occur. Moreover, resistance against antibiotics may develop in almost all groups of micro-organisms, and resistant strains may retain full virulence for man as well as for animals.

TABLE 3. EXAMPLES OF AGENTS THAT MIGHT BE USED TO CAUSE DEATH

Agents	Diseases	Incubation period (days)	Effect of specific therapy	Likelihood of spread from man to man
Viruses	Eastern equine encephalitis	5–15	Nil	Nil[a]
	Tick-borne encephalitis	7–14	Nil	Nil[a]
	Yellow fever	3–6	Nil	Nil[a]
Rickettsiae	Rocky Mountain spotted fever	3–10	Good	Nil[a]
	Epidemic typhus	6–15	Good	Nil[a]
Bacteria	Anthrax	1–5	Moderate	Low
	Cholera	1–5	Good	High
	Plague, pneumonic	2–5	Moderate	High
	Tularaemia	1–10	Good	Low
	Typhoid	7–21	Good	High

[a] Unless vector present.

TABLE 4. EXAMPLES OF AGENTS THAT MIGHT BE USED TO CAUSE INCAPACITATION

Agents	Diseases	Incubation period (days)	Effect of specific therapy	Likelihood of spread from man to man
Viruses	Chikungunya fever	2–6	Nil	Nil[a]
	Dengue fever	5–8	Nil	Nil[a]
	Venezuelan equine encephalitis	2–5	Nil	Nil[a]
Rickettsiae	Q-fever	10–21	Good	Low
Bacteria	Brucellosis	7–21	Moderate	Nil
Fungi	Coccidioidomycosis	7–21	Poor	Nil

[a] Unless mosquito vector present.

Possible bacteriological (biological) agents

168. Victims of an attack by bacteriological (biological) weapons would, in effect, have contracted an infectious disease. The diseases would probably be known, but their symptoms might be clinically modified. For example, apart from the deliberate genetic modification of the organism, the portals of infection might be different from the natural routes, and the disease might be foreign to the geographical area in which it was deliberately spread. Possible bacteriological (biological) agents representing diseases caused by the main groups of relevant micro-organisms are the following.

169. *Anthrax*. Under natural conditions, anthrax is a disease of animals, the main source of infection for man being cattle and sheep.

Its vernacular synonym "wool sorter's disease" indicates one way men used to contract the disease. Depending on the mechanism of transmission, a cutaneous (skin) form (contact infection), an intestinal form (alimentary infection) or pulmonary form (airborne infection) may develop. The lung or respiratory form is most severe, and unless early treatment with antibiotics is resorted to, death ensues within two or three days in nearly every case.

170. Antibiotic prophylaxis is possible but would have to be prolonged for weeks, inasmuch as it has been shown that monkeys exposed to anthrax aerosol die if antibiotic treatment is discontinued after ten days. In certain countries, several types of vaccines are employed, but their effectiveness has not been fully evaluated.

171. The anthrax bacillus forms very resistant spores, which live for many years in contaminated areas and constitute the most dangerous risk the disease presents. From epidemiological observations, the inhalation infectious dose for man is estimated at 20,000 spores. Experiments on animals show that anthrax can be combined with influenza infection or with some noxious chemical agent and that the susceptibility of the animal to airborne anthrax infection is then markedly enhanced.

172. With suitable expertise and equipment large masses of anthrax bacilli can be easily grown, and heavy concentrations of resistant anthrax spore aerosols can be made. Such aerosols could result in a high proportion of deaths in a heavily exposed population. Immunization could not be expected to protect against a heavy aerosol attack. The soil would remain contaminated for a very long time and so threaten livestock farming.

173. *Coccidioidomycosis.* This disease, which is also called desert fever, is caused by a fungus found in the soil of deserts in the United States, South America and the USSR. The spores of the fungus are very stable and can easily be disseminated as an aerosol. If they are inhaled, pneumonia with fever, cough, ague and night-sweating and muscle pains follow after an incubation period of from one to three weeks. In most cases, recovery from the disease occurs after some weeks of illness. An allergic rash sometimes breaks out during the first or second week of the illness and can be significant for proper diagnosis. Treatment presents great difficulties.

174. *Plague.* Under natural conditions, small rodents, from which the disease is transmitted by fleas, are the main source of human infection with plague. This is how "bubonic" plague develops. If the plague microbes are inhaled, pneumonic plague develops after a three-to-five-day incubation period. The patient suffers from severe general symptoms and, if untreated, normally dies within two to three days. A patient with pneumonic plague is extremely contagious to contacts.

175. Preventive vaccination is moderately effective against bubonic, but not pneumonic, plague. If administered early, streptomycin treatment may be successful.

176. In a study of experimental pulmonary plague in monkeys, it was found that an average dose of only 100 bacteria caused fatal disease in half the animals tested. Animal experiments have also shown that particles of one micron diameter (125,000th of an inch), containing single microbial cells, can cause primary pneumonia, with a rapid and fatal outcome. If the aerosol is formed by larger particles (5-10 microns diameter), microbial cells are deposited in the nose and other regions of the upper respiratory tract, and primary foci of the disease develop in the corresponding lymphatic nodes. A fatal generalized infection may then follow.

177. A large mass of plague bacteria could be grown and probably lyophilized (freeze-dried) and kept in storage. The agent is highly infectious by the aerosol route, and most populations are completely susceptible. An effective vaccine against this type of disease is not known. Infection might also be transmitted to urban and/or field rodents, and natural foci of plague may be created.

178. *Q-fever.* Under natural conditions, Q-fever is a disease of animals, the main sources of infection to man being sheep, goats and cattle. The infection is transmitted most frequently by the air route.

179. An incubation period of two to three weeks follows the inhalation of the infectious material. A severe attack of an influenza-like illness follows, with high fever, malaise, joint and muscle pains, which may be followed in five to six days by pneumonia. In untreated cases, the illness lasts from two to three weeks; the patient feels exhausted and is unable to do normal work for several weeks. But the disease can be successfully treated with broad-spectrum antibiotics (tetracyclines). Prophylactic vaccines have been prepared in some countries but have not yet been proved suitable for large-scale use.

180. The agent causing the disease is a rickettsia and is extremely infectious for man. An epidemic of Q-fever once occurred due to contaminated dust which was carried by the wind from a rendering plant some ten kilometres away. Q-fever is also a common and significant laboratory hazard, even though it is only rarely transmitted from man to man. The high susceptibility of humans to this agent has been demonstrated in volunteers.

181. Q-fever rickettsiae are extraordinarily resistant to environmental factors, such as temperature and humidity. Very large amounts can be produced in embryonated chicken eggs (20,000 million micro-organisms per millilitre) and can be stored for a long period of time. A Q-fever aerosol could produce an incapacitating effect in a large proportion of the population of an attacked area. The infective agent could persist in the environment for months and infect animals, possibly creating natural foci of infection.

182. *Tularaemia.* Under natural conditions, tularaemia is a disease of wild animals, the source of human infection being rodents, especially rabbits and hares. When it occurs naturally in human beings, who are very susceptible to the disease, skin lesions and swelling of the lymph nodes are its usual manifestation (infection by contact with sick or dead animals or by way of ticks and other vectors). Infection can also occur through the eye and the gastro-intestinal tract. The pulmonary form (airborne infection) is the more serious. Pulmonary tularaemia is associated with general pain, irritant cough, general malaise etc., but in Europe and Japan mortality due to this form of the disease was never higher than 1 per cent, even before antibiotics became available. American tularaemia strains, on the other hand, are much more dangerous; some epidemics have been associated with a mortality rate as high as 20 per cent, despite antibiotic treatment. Usually treatment with streptomycin or tetracyclines is highly effective. A tularaemia vaccine developed in the USSR is also highly effective.

183. The agent causing the disease is a microbe which is very sensitive to common disinfectants but is able to survive for as long as a few weeks in contaminated dust, water etc.

184. Aerosols of tularaemia have been tested on volunteers. The inhalation infectious dose for man is about 10-25 microbes, and the incubation period five days. By increasing the inhaled dose a hundred times, the incubation period shortens to two to three days. Owing to its easy aerosol transmission, tularaemia has often infected laboratory workers.

185. The microbiological characteristics are similar to those of the plague bacillis (although antibiotic treatment and vaccination prophylaxis are effective). Both lethal and incapacitating effects are to be expected. The disease is not transferred from man to man, but long-lasting natural foci might be created.

186. *Venezuelan equine encephalitis virus (VEE).* In nature, VEE is an infection of animals (equines, rodents, birds) transmitted to man through mosquitos which have fed on infected animals.

187. The disease has sudden onset, with headache, chills and fever, nausea and vomiting, muscle and bone pains, with encephalitis occurring in a very small proportion of cases. The mortality rate is very low, and recovery is usually rapid after a week, with residual weakness often persisting for three weeks. No specific therapy is available. The vaccine is still in the experimental stage.

188. Numerous laboratory infections in humans have been reported, most of them airborne. In laboratory experiments, monkeys were infected with aerosolized virus at relatively low concentrations (about 1,000 guinea pig infectious doses).

189. Inasmuch as the virus can be produced in large amounts in tissue culture or embryonated eggs and airborne infection readily

occurs in laboratory workers, concentrated aerosols could be expected to incapacitate a very high percentage of the population exposed. In some areas, persistent endemic infection in wild animals would be established.

190. *Yellow fever.* In nature, yellow fever is primarily a virus disease of monkeys, transmitted to man by a variety of mosquitoes (*Aedes aegypti, Aedes simpsoni, Hemagogus* species etc.). After an incubation period of from three to six days, influenza-like symptoms appear with high fever, restlessness and nausea. Later, the liver and the kidneys may be seriously affected, with jaundice and diminished urinary excretion supervening. The very severe forms end in black vomitus and death. In a non-immune population, mortality rates for yellow fever may be as high as 30-40 per cent. There is no specific treatment, but prophylactic vaccination, being highly effective, is widely used in yellow fever endemic areas.

2. Effects on populations

191. Other than for sabotage, the use of aerosol clouds of an agent is the most likely form of attack in bacteriological (biological) warfare. For example, material can be produced containing infective micro-organisms at a concentration of 10,000 million per gram. Let us suppose that an aircraft were to spray such material so as to produce an aerosol line source 100 kilometres in length across a 10 kilometre per hour wind. Then, assuming that 10 per cent of organisms survived aerosolization, and that subsequent environmental stresses caused them to die at a rate of 5 per cent per minute, about 5,000 square kilometres would be covered at a concentration such that 50 per cent of the unprotected people in the area would have inhaled a dose sufficient to infect them, assuming that the infective dose is about 100 micro-organisms per person. This particular calculation is valid for agents such as those which cause tularaemia or plague, as well as for some viruses. The decay rate of the causative agents of Q-fever, anthrax and some other infections is much lower, and the expected effect would be still greater.

192. The effects of bacteriological (biological) attacks obviously would vary according to circumstances. Military personnel equipped with adequate protective measures, well trained in their use and provided with good medical services could, if warned of an attack, be able to protect themselves to a considerable degree. But effective early warning and detection systems do not yet exist. On the other hand, attacks on civil populations are likely to be covert and by surprise, and, at present, no civilian populations are protected. Unprotected military or civilian personnel would be at complete risk, and panic and irrational behaviour would complicate the effects of the attack. The heavy burden that would be imposed on the medical services of the

attacked region would compound disorganization, and there would be a major risk of the total disruption of all administrative services.

193. In view of the extensive antipersonnel effects associated with agents of the kind with which this report is concerned, it is useful to view them against the area of effect of a one-megaton nuclear explosion, which, as is well recognized, would be sufficient to destroy utterly a town with a population of one million. It should, of course, be emphasized that direct comparisons of the effects of different classes of weapons are, at best, hypothetical exercises. From the military point of view, effectiveness of a weapon cannot be measured just in terms of areas of devastation or numbers of casualties. The final criterion will always be whether a specific military objective can be achieved better with one than another set of weapons. The basic hypotheses chosen for the comparison are rather artificial; and, in particular, environmental factors are ignored. But despite this limitation, table 5 gives data that help to place chemical, bacteriological (biological) and nuclear weapons in some perspective as to size of target area, numbers of casualties inflicted and cost estimates for development and production of each type of weapon. The figures speak for themselves.

TABLE 5. COMPARATIVE ESTIMATES OF DISABLING EFFECTS OF HYPOTHETICAL ATTACKS ON TOTALLY UNPROTECTED POPULATIONS USING A NUCLEAR, CHEMICAL OR BACTERIOLOGICAL (BIOLOGICAL) WEAPON THAT COULD BE CARRIED BY A SINGLE STRATEGIC BOMBER

	Type of weapon		
Criterion for estimate	*Nuclear (one megaton)*	*Chemical (15 tons of nerve agent)*	*Bacteriological (biological)*[a] *(10 tons)*
Area affected	Up to 300 km^2	Up to 60 km^2	Up to 100,000 km^2
Time delay before onset of effect	Seconds	Minutes	Days
Damage to structures	Destruction over an area of 100 km^2	None	None
Other effects	Radioactive contamination in an area of 2,500 km^2 for 3-6 months	Contamination by persistence of agent from a few days to weeks	Possible epidemic or establishment of new endemic foci of disease
Possibility of later normal use of affected area after attack	3-6 months after attack	Limited during period of contamination	After end of incubation period or subsidence of epidemic
Maximum effect on man	90 per cent deaths	50 per cent deaths	50 per cent morbidity; 25 per cent deaths if no medical intervention

TABLE 5 (*continued*)

Multiyear investment in substantial research and development production capability[b]	$5,000-10,000 million	$1,000-5,000 million	$1,000-5,000 million

[a] It is assumed that mortality from the disease caused by the agent would be 50 per cent if no medical treatment were available.

[b] It is assumed that indicated cumulative investments in research and development and production plants have been made to achieve a substantial independent capability. Individual weapons could be fabricated without making this total investment.

3. EFFECTS ON ANIMALS

194. The way bacteriological (biological) weapons might be used against stocks of domestic animals would probably be the same as that used in attacks against man. Representative diseases and their characteristics are shown in table 6.

195. Viral infections probably cause the most important diseases of domestic animals and could have more devastating effects than diseases produced by other types of pathogens. Since many of the organisms that cause infectious diseases in domestic animals are also pathogenic for man, and since some of them may also be readily transmitted from animals to man, either directly or by vectors, such attacks might also affect the human population directly. Attacks upon livestock would not only result in the immediate death of animals but might call for compulsory slaughter as a means of preventing the spread of infection.

196. Covert bacteriological (biological) attack during peacetime directed against domestic animals could give rise to serious political and economic repercussions if large numbers of stock were affected. For example, African swine fever occurs endemically on the African continent as a subclinical disease of warthogs. In 1957 it was accidentally brought from Angola to Portugal, and then in 1960 to Spain. Despite strict and extensive veterinary measures that were enforced, losses in pig breeds were estimated to amount within a single year to more than $9,000,000.

197. Isolated attacks against stocks of domestic animals during wartime would have only a nuisance value. However, if a highly infectious agent (e.g., foot-and-mouth disease) were used, even a local attack could have very widespread effects because of spread by the normal commercial movement of animals, particularly in highly developed countries. Extensive attacks with travelling clouds could, however, lead to a disastrous state of affairs. The history of myxamatosis (a rabbit

disease) in Europe provides a parallel. Not only did it drastically reduce the rabbit population in France, into which it was first introduced; it immediately spread to other countries of Europe, including the United Kingdom. The risk of the uncontrolled spread of infection to a number of countries is an important consideration in the use of some bacteriological (biological) weapons.

198. The possibilities of protecting domestic animal stocks against bacteriological (biological) attacks are so remote that they are not worth discussing.

TABLE 6. EXAMPLES OF DISEASES THAT MIGHT BE USED TO ATTACK DOMESTIC ANIMALS

Disease	*Animals attacked*
Viruses:	
African swine fever	Hogs
Equine encephalitis	Horses
Foot-and-mouth disease	Cattle, sheep, hogs
Fowl plague	Chickens, turkeys
Hog cholera	Hogs
Newcastle disease	Chickens, turkeys
Rift Valley fever	Cattle, goats, sheep
Rinderpest	Cattle, sheep, oxen, goats, water buffaloes
Vesicular stomatitis	Cattle, horses, mules, hogs
Rickettsiae:	
Veldt disease	Cattle, sheep, goats
Q-fever	Cattle, sheep, goats
Bacteria:	
Anthrax	Cattle, sheep, horses, mules
Brucellosis	Cattle, sheep, goats, hogs, horses
Glanders	Horses, mules
Fungi:	
Lumpy jaw	Cattle, horses, hogs
Aspergillosis	Poultry, cattle

4. EFFECTS ON PLANTS

199. Living micro-organisms could also be used to generate diseases in crops which are economically important either as food or as raw material (e.g., cotton and rubber). Significant food crops in this respect include potatoes, sugar-beet, garden vegetables, soya beans, sorghum, rice, corn, wheat and other cereals and fruits. Obviously, the selection of the target for a biological attack would be determined by the relative importance of the crop in the national diet and economy. Deliberately induced epiphytotics (plant disease epidemics) could in theory have serious national and international consequences.

200. The fungal, bacterial or viral agents which could be used against plants are shown in table 7.

201. With a few minor exceptions, the plant viruses could be cultured only in living plant systems, the causal agent being found only in the plant tissues and juices. Virus diseases are transmitted principally by insect vectors and to some extent by mechanical means.

202. Bacterial agents which attack plants can persist for months on or in the plants. All of them can be cultured on artificial media. Normally, plant bacteria are not disseminated to any great extent by winds; the principal methods for spread in nature are insects, animals (including man) and water. Rain can spread bacteria locally, but insects and animals are responsible for their more extensive spread. It is conceivable bacterial plant pathogens could be adapted for deliberate aerial dissemination.

203. Plant fungi, which cause some of the most devastating diseases of important agricultural crops, are disseminated mainly by winds, but also by insects, animals, water and man. Many fungal pathogens produce and liberate into the air countless numbers of small, hardy spores which are able to withstand adverse climatic conditions. The epidemic potential of a number of fungal pathogens is considerable.

204. In theory there are measures which could protect crops against bacteriological (biological) attacks; but at present their potential cost rules them out in practice. There is no essential difference between the measures which would have to be introduced to counter bacteriological (biological) weapons and those employed normally to control plant diseases in peacetime. But the use of bacteriological (biological) weapons to destroy crops on a large scale would imply

TABLE 7. EXAMPLES OF DISEASES THAT MIGHT BE USED TO ATTACK PLANTS

	Diseases	*Likelihood of spread*
Viruses	Corn stunt	High
	Hoja blanca (rice)	High
	Fiji disease (sugar cane)	High
	Sugar-beet curly top	High
	Potato yellow dwarf	High
Bacteria	Leaf blight (rice)	High
	Blight of corn	High
	Gummosis of sugar cane	Low
Fungi	Late blight (potato)	Very high
	Cereal rusts	Very high
	Rice blast	Very high
	Corn rust	High
	Coffee rust	Very high

that the attacker would choose agents capable of overcoming any known, economical method of protection. Advanced countries might, as a precautionary measure, exchange susceptible plants by more resistant strains. This would be difficult for countries which, because their agricultural standards are not high, would be the most vulnerable to bacteriological (biological) attacks on their crops.

5. Factors influencing the effects of bacteriological (biological) attacks

Exotic diseases

205. Any country that resorted to bacteriological (biological) warfare would presumably try to infect, with a single blow, a large proportion of an enemy population with an exotic agent to which they had not become immune through previous exposures. Such exotic agents would lead to the appearance of diseases which normally had not occurred before in a given geographical area, either because of the absence of the organism involved (e.g., foot-and-mouth disease in North America or Japan), and/or of natural vectors (e.g., Japanese or Venezuelan encephalitis in Europe, Rocky Mountain spotted fever in many countries). In addition, a disease which had been controlled or eradicated from an area (e.g., urban or classical yellow fever from many tropical and subtropical countries, epidemic typhus from developed countries) might be reintroduced as a result of bacteriological (biological) warfare.

Altered or new diseases

206. Deliberate genetic steps might also be taken to change the properties of infectious agents, especially in antigenic composition and drug resistance. Apart from genetic changes that could be induced in known organisms, it is to be expected that new infectious diseases will appear naturally from time to time and that their causative agents might be used in war. However, it could not therefore be assumed that every outbreak of an exotic or new disease would necessarily be a consequence of a bacteriological (biological) attack. The Marburg disease, which broke out suddenly in 1967 in Marburg, Frankfurt and Belgrade, was a good example. It was acquired by laboratory workers who had handled blood or other tissues of vervet monkeys which had been recently caught in the wild, and by others who came into contact with them. Because the outbreak occurred in medical laboratories it was very skilfully handled. In other circumstances, it might have spread widely before it was controlled.

Epidemic spread

207. As already emphasized, a wide variety of agents can infect by the inhalation route, so that in a bacteriological (biological) attack

a large number of persons could be infected within a short time. From the epidemiological point of view, the consequences would differ, depending on whether the resultant disease was or was not transmissible from man to man. In the latter case the result would be a once-for-all disaster, varying in scale and lethality according to the nature of the organism used and the numbers of people affected. The attack would undoubtedly have a strong demoralizing effect on the unaffected as well as the affected population, and it would be in the nature of things that there would be a breakdown of medical services.

208. If the induced disease was easily transmissible from man to man, and if it was one against which the population had not been effectively immunized, it is possible to imagine what could happen by recalling, say, the periodical appearance of new varieties of influenza virus, e.g., the 1957 influenza pandemic. In Czechoslovakia (population about 14 million), 1,500,000 influenza patients were actually reported; the probable total number was 2,500,000. About 50 per cent of the sick were people in employment, and their average period away from work was six days. Complications necessitating further treatment developed in 5-6 per thousand of the cases, and about 0.2 per thousand died. Those who are old enough to remember the 1918 influenza pandemic, which swept over most of the world, will judge the 1957 outbreak as a mild affair.

Susceptibility of population

209. A very important factor in the effectiveness of an aerosol attack is the state of immunity of the target population. Where the population is completely lacking in specific immunity to the agent which is disseminated, the incidence and severity of disease are likely to be exceptionally high. Naturally occurring examples of very severe epidemics in virgin populations are well known (e.g., measles in Fiji, poliomyelitis and influenza in the Arctic). A similar result follows the introduction of a susceptible population (often a military force) into an already infected area. Thus there was a high prevalence of dengue fever in military forces operating in the Pacific in the Second World War—sometimes affecting as many as 25 per cent of the operational strength of a unit. The local population suffered relatively little from the disease because it had usually been infected early in life and was subsequently immune.

Populations of increased vulnerability

210. *Malnutrition.* Recent statistical studies reveal a clear association between malnutrition and the incidence of infectious diseases. The Food and Agriculture Organization (FAO), the World Health Organization (WHO) and the United Nations Children's Fund (UNICEF) have pointed out that in developing countries a shortage of nutritious food is a major factor in the high mortality rate due to infectious diseases, particularly in children.

211. *Housing and clothing.* Primitive housing and inadequate clothing would lead to an increased vulnerability to bacteriological (biological) weapons and, more particularly, chemical weapons. Millions of people live in houses which are permeable to any sort of airborne infection or poison, and millions are inadequately clothed and walk barefooted.

212. Other conditions which characterize poor populations have a definite influence on the spread of infections. Large families increase the opportunities for contagious contact. Inadequate housing, lack of potable water and, in general, bad sanitation, a low educational level, numerous vectors of infectious disease (e.g., insects), and, of course, a lack of medical services are factors which also favour the spread of disease. The agents used might also persist in the soil, on crops, grasses etc., so that delayed action might need to be taken into account.

Social effects and public health measures

213. A basic factor which influences the risk of epidemic situation during every war is a rapid impairment of standards of hygiene. Widespread destruction of housing and of sanitary facilities (water works, water piping, waste disposal etc.), the inevitable decline in personal hygiene and other difficulties create exceptionally favourable conditions for the spread of intestinal infections or louse-transmitted disease, etc.

214. The importance of adequate public health services is well illustrated by an explosive water-borne epidemic of infectious hepatitis in Delhi in 1955-1956, which affected some 30,000 persons and which occurred because routine water treatment was ineffective. That epidemic was caused by the penetration into the water supply of waste waters heavily contaminated with hepatitis virus. However, there was no concurrent increase in the incidence of bacillary dysentery and typhoid fever, showing that the routine treatment of the water had been adequate to prevent bacterial but not viral infections.

215. Air streams, migrating animals and running water may transport agents from one country to the other. Refugees with contagious diseases pose legal and epidemiological problems. In areas with multinational economies, losses in livestock and crops may occur in neighbouring countries by the spread of the disease through regional commerce.

216. The experiences from fairly recent smallpox epidemics can also be used to illustrate the social effects of an accidentally introduced, highly dangerous airborne infection. In New York (1947) one patient started an epidemic, in which twelve persons became ill and two died. Within a month more than 5 million persons were revaccinated. Similarly in Moscow, in January 1960, a smallpox epidemic of forty-six cases (of whom three died) developed, caused by

a single patient. At that time 5,500 vaccination teams were set up and vaccinated 6,372,376 persons within a week. Several hundreds of other health workers searched a large area of the country for contacts (9,000 persons were kept under medical supervision, and of these 662 had to be hospitalized as smallpox suspects).

Chapter III

ENVIRONMENTAL FACTORS AFFECTING THE USE OF CHEMICAL AND BACTERIOLOGICAL (BIOLOGICAL) WEAPONS

A. General considerations

217. Extraneous factors influence the behaviour of chemical and bacteriological (biological) weapons to a far greater extent than they do any other kind of armament. Some, such as wind and rain, relate to the state of the physical environment and, to a certain extent, can be evaluated quantitatively. Others, which reflect the general ecological situation, and the living conditions and physiological state of the populations exposed to the effects of the weapons, are more difficult to define; their influence—although they could be considerable—cannot be quantified.

218. This limitation applies particularly to bacteriological (biological) weapons. The natural course of infectious diseases—for example, in influenza epidemics—shows that they are governed by so many uncontrollable factors that the way they develop cannot as a rule be foreseen. This would also be probably true of pathogenic agents which were deliberately dispersed. On the other hand, the knowledge gained through the study of epidemiology and the study of artificial dispersions of bacteriological (biological) agents, both in the laboratory and the field, has shed some light on some of the factors concerned.

219. The ecological problem is the main theme of chapter IV. The factors which concern the variability of the human target, e.g., physiological and living conditions, and levels of protection, have already been described in chapters I and II. This chapter is concerned with the physical environment (climate, terrain).

1. Phenomena associated with the dispersal of chemical and bacteriological (biological) agents

220. It has already been pointed out that chemical substances and living organisms capable of being used as weapons are extremely varied in their nature and in their effects. On the other hand, regarded solely from the standpoint of their physical state after dispersion in the atmosphere, they can clearly be placed in one or other of the following categories:

(*a*) Liquid drops and droplets of varying size (diameters greater than about 10 microns);

(*b*) More or less finely divided liquid and solid aerosols (diameters less than about 10 microns);

(*c*) Vapours.

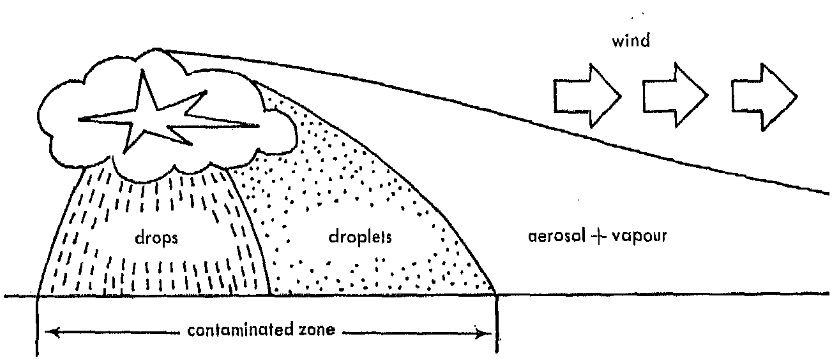
221. Almost always, moreover, especially in the case of liquid chemical agents, the result of dispersion is a mixture of these different phases; thus, a liquid dispersed by an explosive charge gives rise to a mixture of aerosol and vapour, and aerial spraying may produce a mixture of droplets and aerosols. Solid chemical substances will be in aerosol form, and this will also be true, as has already been pointed out, of bacteriological (biological) agents.

222. Thus, chemical attacks would usually take effect simultaneously in two forms (figure IV):

(*a*) Contamination of the ground at, and in the immediate vicinity of, the target by direct deposition of the agent at the time of dispersion and by subsequent settling of large particles;

(*b*) Formation of a toxic cloud consisting of fine particles, or droplets, of aerosol and possibly of vapour.

FIGURE IV. EFFECT OF THE AERIAL EXPLOSION OF A CHEMICAL PROJECTILE



223. Most bacteriological (biological) attacks would be designed primarily to create an infectious aerosol as an inhalation hazard. Some ground contamination, however, might also result when infectious particles settled on the ground.

224. Both ground contamination and toxic or infectious clouds would be immediately subject to the physical action of the atmosphere.

225. If the soil contaminants were liquid chemical agents, they would either evaporate, producing a sustained secondary cloud, or be absorbed by the ground, or diluted or destroyed by atmospheric pre-

cipitation. If they were solid agents, whether chemical or biological, they might be returned to a state of suspension by air currents and perhaps carried out of the initially contaminated zone.

226. As it becomes formed, the toxic or infectious cloud is immediately exposed to atmospheric factors and is straightaway carried along by air currents. At the same time, the particles within it are deposited at different rates according to their mass and reach the ground at varying distances from the point of emission, depending on wind velocity (up to several kilometres in the case of particles less than a few tens of microns in diameter). The mechanically stable fraction of the aerosol (particles under 5 microns in diameter) remains in suspension and may be carried along for considerable distances.

B. The influence of atmospheric factors on clouds of aerosols or vapours

227. The movement of a toxic or infectious cloud after its formation depends chiefly on the combined effects of wind and atmospheric conditions. The cloud is carried a longer or shorter distance by the wind; at the same time it is dispersed and diluted at a faster or slower rate by turbulence of the atmosphere and by local disturbances of mechanical origin resulting from the roughness of the ground.

228. The cloud may rise rapidly in the atmosphere or remain in the immediate vicinity of the ground, thus retaining its destructive power for a greater or lesser time, depending on whether the air layer in which it is released is in a stable or unstable state.

1. State of the atmosphere

229. The state of the atmosphere plays such an important role in the behaviour of aerosol clouds that one might almost say that it is the predominant factor in determining the outcome of an attack, the effect of which could be considerably reduced, or almost nullified, if the atmosphere was very unstable, or very serious if it was in a state of pronounced and prolonged stability. For this reason the mechanisms governing the turbulent movements of air, caused by differences in temperature between superimposed air layers require some explanation (see figure V).

230. Disregarding the frictional layer of air close to the ground, where mechanical turbulence resulting from friction between the air and the rough ground over which it moves creates special conditions, air temperature in the troposphere decreases on average at the rate of 0.64°C for every 100 metres of altitude. Very frequently, however, as a result of thermal exchange between the air and the ground, a cooler air layer may be formed beneath a mass of hot light air; in such conditions, the lower air layer, with its greater density, does not tend to rise, and the atmosphere is said to be in "stable equilibrium".

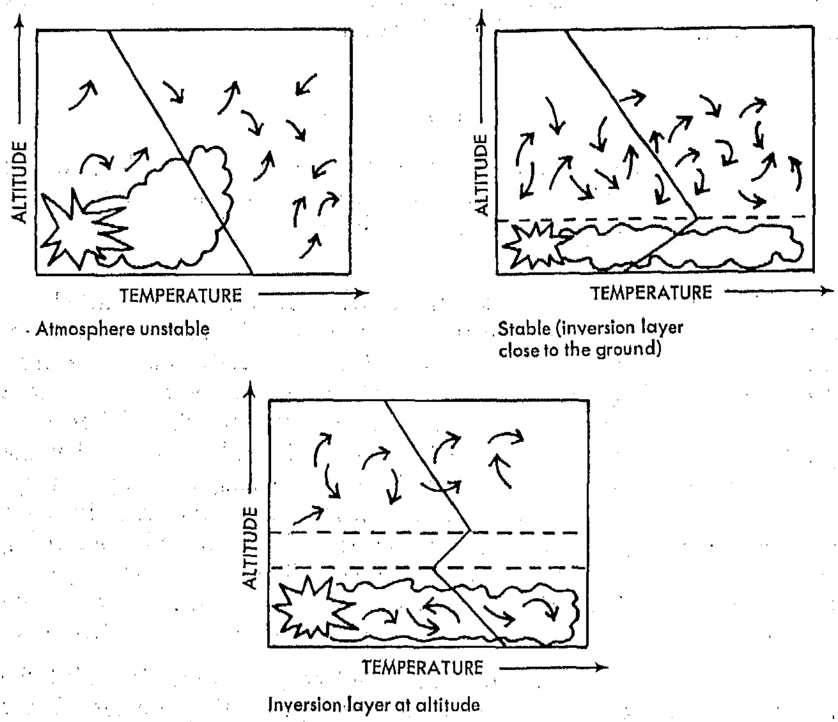
231. The situation, in which the vertical temperature gradient becomes inverted, is known as "temperature inversion", and the air layer affected by the phenomenon is termed "inversion layer". When present it is eminently favourable to the persistence of toxic clouds.

232. After a day of sunshine, the surface of the ground cools rapidly, with the result that the layer of air close to the ground cools more rapidly than those above it. Both the intensity of the inversion and the thickness of the air layer involved increase to a maximum towards 4 a.m., and then decrease again, finally disappearing shortly after sunrise. This variation is very marked when the sky is clear, and in favourable conditions the inversion may last from fourteen to eighteen hours a day, depending on the season.

233. Very often, however, especially in winter or in overcast weather, when the rays of the sun are not sufficiently intense to heat the surface of the ground, the temperature inversion may last for several days. This condition has characterized all the disasters caused by industrial pollution; for example, the smog which claimed 4,000 victims in London in 1952 took its toll during a period of atmospheric stability which lasted for seven days.

234. Figure V shows the evolution of a toxic cloud depending on the state of the atmosphere.

FIGURE V. EFFECT OF INVERSION LAYERS ON AEROSOL AND VAPOUR CLOUDS



235. Apart from this kind of low-altitude inversion, which is most important in the context of this report since it governs the behaviour of toxic clouds released close to the ground, a similar process may take place on a large scale at higher altitudes (hundreds or thousands of metres) whenever a cool air layer is formed beneath a hot air mass. This may take place over large, cold expanses (i.e., large expanses of land or sea, cloud or fog masses etc.). Because of the high altitude at which they form, these inversion layers have little effect on toxic clouds released at ground level; but in the case of the long-distance transfer of spores they may act as a screen or reflector.

236. The configuration of the surface of the earth in a particular area, which alters the thermal exchange pattern, may also be conducive to the formation of an inversion. For example, inversions are a customary phenomenon in winter in deep valleys surrounded by high peaks and occur more frequently in the neighbourhood of slopes facing the north than on southern slopes. They also occur wherever hills of any size enclose a plain or basin, interrupting the general flow of air and preventing mixing from taking place. It is interesting to note that, apart from the periodic appearance of smog in London, all the other major accidents resulting from air pollution have occurred in regions where the land configuration fits this description. For example, the small town of Donora, in the United States, lies in a relatively narrow plain bordered by high hills. In 1948 air pollution in the course of an inversion lasting five days led to twenty deaths and 6,000 cases of illness among the town's 14,000 inhabitants.

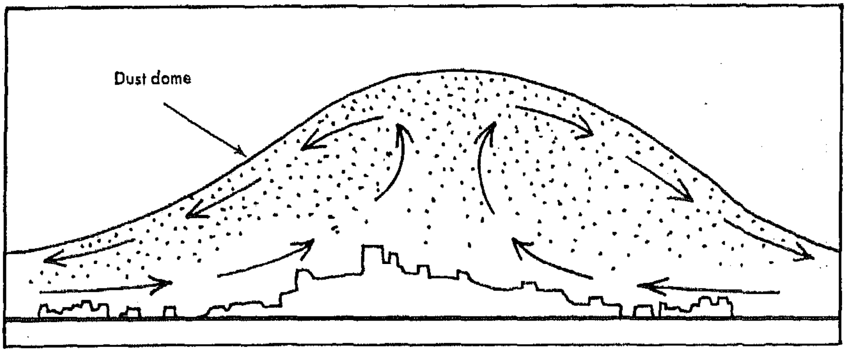
2. Urban areas

237. The case of urban built-up areas is more complex, and it may even be said that each one possesses its own microclimate, depending on its geographical situation, its topography and the layout and nature of its buildings.

238. Because the materials from which they are constructed are better conductors, and because their surfaces face in very varied directions, buildings usually capture and reflect solar radiation better than does the natural ground. Urban complexes therefore heat up more quickly than does the surrounding countryside, and the higher temperature is still further augmented by domestic and industrial heating plants. The result is a flow of cool air from the neighbouring countryside towards the hot centre of the town, beginning shortly after sunrise, decreasing at the beginning of the afternoon and then rising again to a maximum shortly before sunset (figure VI). This general flow, which is of low velocity, is disturbed and fragmented at ground level by the buildings, forming local currents flowing in all directions.

239. This constant mechanical turbulence, to which is added the thermal turbulence caused by numerous heat-generating sources, should

FIGURE VI. AIR CIRCULATION IN A CITY



prevent the establishment in towns of a temperature inversion at low altitude. In fact, however, inversions do occur, when conditions are otherwise favourable but the inversion layer is situated at a higher altitude than over the surrounding countryside (30 to 150 metres).

240. At night, local inversions may be generated at low altitude as a result of rapid radiation from the roofs of houses; thus in a narrow street lined with buildings of equal height, an inversion layer may be created at roof-top level which will persist until dawn.

241. Fog is more frequent over towns than over open country (+30 per cent in summer and +100 per cent in winter). The process of fog formation is accelerated by the particles, dust and smoke which form a dome over the town. At night these particles act as nuclei around which the fog condenses, the fog contributing in its turn to the retention of the particles in the dome. Fog will obviously have the same concentrating effect on particles originating in toxic clouds.

242. One final point which should be noted is that toxic aerosols and vapours may take some time to penetrate enclosed spaces. Once they have done so, they may continue as a hazard for very long unless adequate ventilation is provided.

3. EFFECT OF WIND AND TOPOGRAPHY

243. The wind carries and spreads the toxic or infectious cloud, which is simultaneously diluted by turbulence. The distance which the cloud travels before its concentration has fallen to a level below which it is no longer harmful depends on the velocity of the wind and the state of the atmosphere. Inasmuch as topography also produces changes in the normal wind pattern, it, too, plays an important part in determining the direction of travel of toxic clouds, sometimes focusing their effects in individual areas. Local winds may also be established as a result of differences in the heat absorbed by, and radiated from, different ground surfaces.

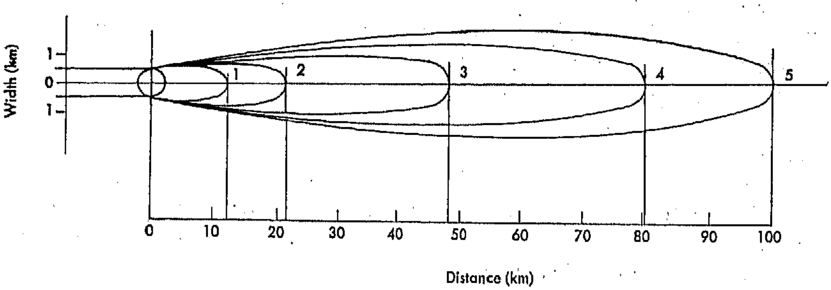
244. These local surface winds, which affect the air layer nearest the ground up to 300 metres, are frequent and widespread in mountain ranges and near sea coasts. There are slope breezes, valley breezes and land breezes; and they could shift a toxic cloud in directions which cannot be predicted from a study of the general meteorology of the area. The breezes develop according to a regular cycle. During the day, under the influence of solar radiation, the air moves up the valleys and slopes and moves from the sea towards the land; at night these currents are reversed. In temperate climates land and sea breezes are predominant during the summer; but they are masked by the general wind pattern during the other seasons of the year. They are predominant in subtropical and tropical regions throughout the year.

4. Example of combined effects of wind and the state of the atmosphere on a cloud

245. There is some similarity between the evolution of toxic clouds which could be produced by chemical and bacteriological (biological) attacks and that of clouds containing industrial pollutants, so much so that the mathematical models developed for forecasting atmospheric pollution can be applied, with a few modifications, to toxic clouds. But the initial characteristics of the two are as a rule different. Characteristic features of chemical or bacteriological (biological) attacks are the multiplicity and high yield of the sources of emission and their very short emission time, all of which are factors making for a greater initial concentration in the cloud than the concentration of pollutants in industrial clouds.

246. Figure VII indicates the order of magnitude of these phenomena and demonstrates the schematic form and, for different atmospheric conditions, the size of area which would be covered by toxic clouds originating from a chemical attack using Sarin, with an intensity arbitrarily chosen at 500 kg/km. It shows that the theoretical distance of travel by the cloud, determined for bare and unobstructed

Figure VII. Effect of atmospheric stability on the dimensions of the affected areas (Sarin). Source intensity: 500 kg/km. Wind velocity = 7 km/h.



ground, may exceed 100 km. In practice the atmosphere must remain stable for more than ten hours in order to enable the cloud to travel such distances, a condition which, although certainly not exceptional, is fairly uncommon.

247. This figure illustrates the effect of atmospheric conditions on the distance that a toxic cloud can be carried by the wind.

248. The example chosen is that of a medium-intensity (500 kg) attack with Sarin on a circular objective 1 km in diameter. The wind velocity is 7 km/h.

249. Each of the lines represents a contour of the hazard zone, i.e., the zone in which any unprotected person would be exposed to the effects of the agent.

250. Under highly unstable conditions (for example, on a very sunny day), this hazard zone is no greater than the area of objective aimed at (the circle at the left end of the figure). On the other hand, in any other situation—(1) slightly unstable, (2) neutral, (3) slightly stable, (4) moderately stable or (5) highly stable—the distance travelled will be greater, and it may extend almost 100 km if conditions remain highly stable for a sufficiently long time. It must be noted, however, that the distance of 100 km could be reached only if a very marked inversion persisted for about fourteen hours (100 + 7); such a situation is quite rare.

251. Corresponding evaluations cannot be made for an urban area, since the parameters involved are too numerous and too little understood. But it may be presumed that most of the characteristics of the urban microclimate would tend to increase the persistence of chemical clouds. This is serious cause for concern, when it is remembered that in highly industrialized countries 50 to 90 per cent of the population live in urban areas.

252. To sum up, a stable or neutral atmosphere in equilibrium might cause a toxic cloud produced by a chemical or bacteriological (biological) attack to persist for hours after it had exercised its military effect, which could generally be expected to materialize in the first few minutes following the attack. These conditions could obtain not only at night but during long winter periods over vast continental expanses. If a neutral atmosphere in equilibrium were associated with a light wind irregular in direction, then the area affected could be relatively large, and, assuming an adequately heavy initial attack, the concentrations would be high.

5. Special features of bacteriological (biological) aerosols

253. So far as physical phenomena are concerned (horizontal and vertical movements, sedimentation, dilution etc.), bacteriological (bio-

logical) aerosols would be generally affected in the same way as chemical clouds of aerosol and vapour, but not necessarily to the same extent. But inasmuch as the effective minimum doses for bacteriological (biological) agents are considerably smaller than for chemical agents, bacteriological (biological) aerosols would be expected to remain effective even in a very dilute state and, consequently, could contaminate much larger areas than could chemical clouds. An example is given in chapter II.

254. There would be no limit to the horizontal transport of micro-organisms, if there were none to the capacity of the organisms to survive in the atmosphere. Thus, if the microbial aerosol particles were so small that their speed of fall remained close to the speed of the vertical air movements in the frictional layer (under average conditions this is on the order of 10 cm/s), the agents, whether alive or dead, would remain suspended and travel very considerable distances. Even if bacteriological (biological) clouds were to move only in the air layer nearest the ground, they could cover very large areas. For example, in one experiment 600 litres of *Bacillus globigii* (a harmless spore-forming bacterium which is highly resistant to aerosolization and environmental stresses) were released off shore; bacteria were found more than 30 km inland. Organisms were found over 250 km^2, which was the entire area within which there were monitoring stations during the trial. The actual area covered was much more extensive.

255. On the other hand, most pathogenic agents are highly vulnerable when outside the organism in which they normally reproduce and are liable to biological inactivation, which is sometimes rapid, in the aerosol state. This inactivation process is governed by several factors (such as temperature, humidity, solar radiation) which are now the subject of aerobiological research.

256. The size of the infective particles in a bacteriological (biological) aerosol is highly significant to their ability to initiate disease as a result of inhalation. It has been established that the terminal parts of the respiratory tract are the most susceptible sites for infection by inhalation. As with chemical agents, the penetration and retention of inhaled bacteriological (biological) particles in the lungs is very dependent on particle size, which is primarily determined by the composition of the basic material and the procedure of aerosolization, as pointed out in chapter I.

257. The influence of particle size on aerosol infectivity is illustrated in table 8, which shows that there is a direct relationship between the LD 50 and particle diameter of an aerosol of *Franciscella tularensis*.

TABLE 8. NUMBERS OF BACTERIA OF *Franciscella tularensis* REQUIRED TO KILL 50 PER CENT OF EXPOSED ANIMALS

Diameter of particles (microns)	*Numbers of bacterial cells LD 50*	
	Guinea pigs	*Rhesus monkeys*
1	3	17
7	6,500	240
12	20,000	540
22	170,000	3,000

C. Influence of atmospheric factors on chemical agents

1. INFLUENCE OF TEMPERATURE

258. An attack with a liquid chemical agent, as already pointed out, would as a rule result in the formation of a cloud of small droplets, aerosol and vapour in varying proportions, as well as in ground contamination, all of which would be affected by air temperature.

Influence on droplet and aerosol clouds

259. Only particles having dimensions within certain limits penetrate and are retained by the lungs. The larger ones are trapped in the upper part of the respiratory tract (e.g., nose and trachea), whereas the smaller ones are exhaled. Penetration and retention have maximum values in the size range of 0.5 to 3 microns.

260. Liquid chemical agents exercise their effects both by penetrating the skin and by inhalation. The material absorbed by the lungs acts immediately, whereas there is a delay before the effects become manifest from an agent absorbed through the skin or the mucous membrane of the upper air passages.

261. A high temperature favours the evaporation of particles which will decrease in size and thus reach the lungs, contributing to the immediate effect; an additional quantity of vapour is produced which contributes to the same effect.

Effect on ground contamination

262. The temperature of the air and, even more, that of the ground have a marked effect on the way ground contamination develops and persists. The temperature of the ground, which depends on the thermal characteristics of its constituent materials and on the degree of its exposure to the sun, either increases or reduces evaporation and, consequently, decreases or increases the duration of contamination. The surface temperature is extremely variable from point to point, depending on the type and colour of the soil; a temperature difference of 20° has been noted between the asphalt surface of a road

and the surrounding fields. The temperature gradient also varies during the course of the day; in clear weather the differences may range from 15 to 30°C in a temperate climate, and up to 50°C in a desert climate. High temperatures of both air and ground favour the rate of evaporation, thus reducing the persistence of surface contamination; wind, because of the mechanical and thermal turbulence it creates, has a similar effect.

263. To illustrate the effect of these variable factors, it is worth noting that the contamination of bare ground by unpurified mustard, at a mean rate of 30 g/m², will persist for several days or even weeks at temperatures below 10°C at medium wind velocities, whereas it lasts for only a day and a half at 25°C. Furthermore, because of accelerated evaporation at high temperatures, the cloud produced is more concentrated, and the danger of vapour inhalation in, and downwind of, the contaminated area becomes greater.

2. Influence of humidity

264. In contrast to high temperature, high relative humidity may lead to the enlargement of aerosol particles owing to the condensation of water vapour around the nuclei which they constitute. The quantity of inhalable aerosol would thus diminish, with a consequent reduction in the immediate effects of the attack.

265. On the other hand, a combination of high temperature and high relative humidity causes the human body to perspire profusely. This intensifies the action of mustard-type vesicants and also accelerates the transfer through the skin of percutaneous nerve agents.

3. Influence of atmospheric precipitation

266. Light rain disperses and spreads the chemical agent which thus presents a larger surface for evaporation, and its rate of evaporation rises. Conversely, a heavy rain dilutes and displaces the contaminating product, facilitates its penetration into the ground and may also accelerate the destruction of certain water-sensitive compounds (e.g., lewisite, a powerful blistering agent).

267. Snow increases the persistence of contamination by slowing down the evaporation of liquid contaminants. In the particular case of mustard gas, the compound is converted into a pasty mass which may persist until the snow melts.

268. Soil humidity, atmospheric precipitation and temperature also exercise a powerful influence on the activity of herbicides, which are much more effective at higher humidities and temperatures than in dry weather and at low temperatures. This applies equally to preparations applied to plants and to those introduced into the soil.

4. Influence of wind

269. As vapours emanating from ground contaminated by liquid chemical agents begin to rise, the wind comes into play. The distance the vapours will be carried depends on the wind velocity and the evaporation rate of the chemical, which will itself change with variations in ground and air temperatures. The distance is maximal (several kilometres) when there is a combination of the conditions promoting evaporation (high soil temperature), persistence of the cloud (stable atmosphere) and dispersal of the cloud (gentle winds). These conditions exist in combination at the end of a sunny day, at the time when a temperature inversion exists.

5. Influence of soil-dependent factors

Nature of the soil

270. The soil itself, through its texture and the porosity of its constituent materials, plays an important role in the persistence of liquid chemical contaminants, which may penetrate to a greater or lesser extent or remain on the surface. In the former case the risk of contamination by contact is reduced in the short term, but persistence will be increased to the extent that factors favourable to evaporation (temperature, wind) are prevented from acting. In the latter case, when the contaminant remains on the surface, the danger of contact contamination remains considerable, but persistence is reduced. Thus persistence in sandy soils may be three times as long as in clay.

Vegetation

271. Vegetation prevents a liquid contaminant from reaching the soil and also breaks it up, thus encouraging evaporation. At the same time, the short-term danger is enhanced because of the widespread dispersion of the contaminant on foliage and the consequently increased risk of contact contamination.

272. The canopy of foliage in dense forests (e.g., conifers, tropical jungle), traps and holds a considerable proportion of a dispersed chemical agent, but the fraction which none the less reaches the soil remains there for a long time, inasmuch as the atmospheric factors involved in the process of evaporation (temperature, wind over the soil, turbulence) are hardly significant in such an environment as compared with open spaces.

273. Too little is known about the absorption and retention of toxic substances by plants to make it possible to assess the resulting danger to the living creatures whose food supply they may constitute. Like certain organic pesticides, it is probable that other toxic chemicals may penetrate into plant systems via the leaves and roots. Cases could then arise where all trace of contaminant had disappeared from the soil but with the toxic substance persisting in vegetation.

Urban areas

274. It can also be assumed that, in spite of a surface temperature which is on the average higher, contaminants might persist longer in built-up areas than over open ground. There are two reasons for this. Structural, finishing and other building materials are frequently porous, and by absorbing and retaining liquid chemical agents more readily, they increase the duration of contamination. Equally the factors which, in open country, tend to reduce persistence (sunshine, wind over ground) play a less important part in a built-up city.

275. Climate, in general, may exercise an indirect influence on the effect of percutaneous chemical agents, simply because of the fact that in hot climates the lightly clad inhabitants are very vulnerable to attacks through the skin.

276. The predominating influence of climatic factors and terrain on the persistence of contamination indicates that the *a priori* classification of chemical agents as persistent or non-persistent, solely on the basis of different degrees of volatility, is somewhat arbitrary, because, depending on circumstances, the same material might persist for periods ranging from a few hours to several weeks, or even months.

D. Influence of atmospheric factors on bateriological (biological) agents

277. Infectious agents, when used to infect by way of food and water or by means of animal vectors, are, of course, hardly subject to the influence of climatic factors. But any large-scale attack by bacteriological (biological) agents would probably be carried out by aerosols, in which the agents would be more susceptible to environmental influences than chemical agents.

278. Physico-chemical atmospheric factors have a destructive effect on aerosol-borne micro-organisms. Their viability decreases gradually over a period of hours or days at a progressively diminishing rate. Some decay very rapidly: for example, certain bio-aerosols used for pest control in temperate climates and dispersed under average conditions in the cold or transitional seasons show a rate of decay of 5 per cent per minute.

279. This apparent vulnerability of micro-organism in aerosols might cast some doubt on the possible effectiveness of bacteriological (biological) attacks. However, there are various means by which the rate of decay in the aerosol can be considerably reduced: for example, the use of very high concentrations of agent; the use of suitably "modelled" pathogenic strains; or the protection of aerosol particles by encapsulating them in certain organic compounds.

280. These procedures, which prolong the survival of micro-organisms in air, could presumably also be applied to potential agents of bacteriological (biological) warfare. Means are also available for prolonging the survival of micro-organisms in water, soil etc.

1. Influence of temperature

281. The effect of temperature on the survival of micro-organisms in bacteriological (biological) aerosols is not highly significant in the temperature ranges generally encountered. As a general rule, aerosol-borne biological agents will be destroyed more rapidly the more the temperature rises. On the other hand, in some circumstances, high temperatures may act on bacteriological (biological) aerosols in the same way as on chemical aerosols, that is to say, particle size will be diminished by evaporation, and thus their rate of entry into the lungs will be enhanced.

2. Influence of humidity

282. Relative humidity is the most important of the atmospheric conditions which affect the rate of decrease of viability of micro-organisms in the air. The extent of its effect varies with different micro-organisms, with the nature of the suspending fluid from which the aerosol is disseminated, with the manner of its dissemination (as a spray or as a dry powder). As a general rule, the rate of inactivation is greater at lower relative humidity, although with some organisms maximum inactivation occurs in the middle range of relative humidity (30-70 per cent). The rate of inactivation, however, will tend to decrease with time and may become extremely low when a state of equilibrium (stabilization) between the particles and their environment has been established. This implies that, irrespective of relative humidity values, the final infective concentration of a stabilized aerosol may still be above the threshold minimum dose for infection by inhalation. Even so, microbial survival in a stabilized aerosol may be further reduced by sudden variations in atmospheric humidity.

283. The effectiveness of aerosol-borne bacteriological (biological) agents depends not only on their capacity to survive in the air. Also important is their low rate of sedimentation, combined with the capacity of the micro-organisms to spread and penetrate into buildings, so contaminating surfaces and materials indoors as well as outdoors. The possibility that some infective agents can survive for a long time in such conditions and the fact that environmental dust particles may exercise a protective influence on organisms have been demonstrated on many occasions. Studies made in hospitals have shown that surviving micro-organisms can be dispersed from sites which have come to be called "secondary reservoirs", and that they may become sources of new infections, carried either through the air or by contact.

3. Influence of solar radiation

284. The ultra-violet part of the solar spectrum has a powerful germicidal effect. Bacterial spores are much less sensitive to this radiation than are either viruses or vegetative bacteria, and fungal spores are even less sensitive than bacterial spores. The destructive effect of solar radiation on micro-organisms is reduced when relative humidity is high (over 70 per cent). Air pollution, including a high proportion of atmospheric dust, also provides some protection.

285. Ultra-violet light exercises its destructive effects on micro-organisms through the structural degradation of the nucleic acids which carry the genetic information. Most research on this subject has been carried out on microbes in liquid suspensions, but the results of studies of aerosol-borne microbes seem to lead to similar conclusions.

286. The germicidal effect of ultra-violet radiation has been known for a long time and used in combating airborne infections in schools, military buildings and hospitals. The problems of proper radiation dosage and proper techniques, however, still remain to be solved.

287. The lethal effect of sunlight on micro-organisms is less marked, although still apparent, in diffuse light. This is why a bacteriological (biological) attack, if one ever materialized, would be more probably undertaken in darkness.

4. Influence of atmospheric precipitation

288. Rain and snow have relatively little effect on bacteriological (biological) aerosols.

5. Influence of the chemical composition of the atmosphere

289. Little is known about the influence on the viability of micro-organisms of the chemical compounds present in the atmosphere. Oxygen promotes the inactivation of aerosol-borne agents, particularly in conditions of low humidity, and recent studies have also demonstrated that an unstable bactericidal factor (formed by combination between ozone and gaseous combustion products of petroleum) is present in the air, particularly downwind of heavily populated areas.

6. General effects of climate

290. Climate may also have a general and considerable influence on the development of epidemics and epizootics, in so far as the proliferation of vectors which spread disease may be encouraged, given the right conditions. This is indicated by the way myxomatosis developed in Australia. Although several attempts in 1927, and then from 1936

to 1943, to impart the disease to Australian rabbits failed, the epizootic spread rapidly from 1950 onwards, apparently for the sole reason that the summer, which was particularly rainy that year, was associated with an exceptional proliferation in the flooded Murray River valley of the mosquitoes which carry the disease.

291. Atmospheric humidity and temperature also have a strong influence on micro-organisms acting upon vegetation.

Chapter IV

POSSIBLE LONG-TERM EFFECTS OF CHEMICAL AND BACTERIOLOGICAL (BIOLOGICAL) WARFARE ON HUMAN HEALTH AND ECOLOGY

A. General

292. So far this report has dealt essentially with the potential short-term effects of chemical and bacteriological (biological) warfare. The possible long-term effects of the agents concerned need to be considered against the background of the trends whereby man's environment is being constantly modified, as it becomes transformed to meet his ever-increasing needs. Some of the changes that have occurred have been unwittingly adverse. The destruction of forests has created deserts, and grasslands have been destroyed by over-grazing. The air we breathe and our rivers become polluted, and chemical pesticides, despite the good they do, also threaten with undesirable secondary effects. The long-term impact of possible chemical and bacteriological (biological) warfare clearly needs to be considered within an adequate ecological framework.

293. *Ecology* may be defined as the study of the interrelationships of organisms, on the one hand, and of their interactions with the physical environment in which they are found, on the other. The whole complex of plants and animals within a specific type of environment —a forest, a marsh, a savannah—forms a community comprising all the plant life and all the living creatures, from the micro-organisms and worms in the soil to the insects, birds and mammals above the ground, within that environment, and the understanding of their interrelationships also necessitates a knowledge of the physical characteristics of the environment which bear on the living complex. Ecological communities are normally in dynamic equilibrium, which is regulated by the interaction of population density, available food, natural epidemics, seasonal changes and the competition of species for food and space.

294. Man has his special ecological problems. His numbers are multiplying fast, and increasing population requires commensurate increases in food production. The production and distribution of adequate food for the population which is predicted for the latter part of this century, and which will go on increasing through the next, will allow no relaxation in the effort which has already proved so successful. Food

production has increased phenomenally in the past fifty years, primarily because of (*a*) improved agricultural practices, and particularly because of a marked increase in the use of chemical fertilizers and pesticides; (*b*) the development of genetically improved plants, herds and flocks; and (*c*) increased industrialization of food-producing processes. There is hope that steps such as these will continue to bear fruit.

295. But although the use of fertilizers, herbicides and pesticides has brought about a massive increase in food production, it has also added to the pollution of soil and water and, as a result, has altered our ecological environment in an enduring way. So, too, have other features of our industrial civilization. The motor car has been a very potent factor in increasing air pollution in towns and cities. The increasing population of the world creates unprecedented wastes, and the methods used to dispose of it—burying it, burning it or discharging it into streams or lakes—have further polluted the environment. The remarkable development of synthetic and plastic materials in recent years has also added a new factor to the short- and long-term biological effects on man. Every new advance on our technological civilization helps to transform the ecological framework within which we evolved. From this point of view, the existence and possible use of chemical and bacteriological (biological) agents in warfare have to be regarded as an additional threat, and as a threat which might have enduring consequences, to our already changing environment.

B. Consequences to man of upsetting the ecological equilibrium

296. The chemical industry doubled its output between 1953 to 1960, and it is still growing fast; but the useful results of its continued development are none the less of the utmost importance to man's future. The good effects on food production of the use of artificial fertilizers alone far outweigh any secondary deleterious consequences of their use. The facts are too well known to need spelling out. It is enough to point out, as one example, that maize production in the United States increased between 1923 and 1953, a thirty-year period, by barely four quintals per hectare, but that in the ten years between 1953 and 1964, when the use of fertilizers and more productive hybrid seeds became widespread, the increase was eleven quintals. This is characteristic of what has happened everywhere where fertilizers have been used on a large scale.

297. The beneficial effect of the use of modern chemical pesticides also does not need spelling out. It is estimated that the present annual world loss in production due to weeds and parasites is still approximately 460 million quintals of wheat and 360 million quintals of maize, and that to eliminate this waste will mean the use of even more pesticides than are now being consumed.

298. What has to be realized about modern agricultural practices is that without them the increases in the output of food which the world needs could never be achieved. Unless production mounts everywhere, those who have not yet cast off the burdens of living in a primitive agricultural world will never reach the level of civilization to which all aspire.

299. But, as already indicated, the great increase in the use of fertilizers, pesticides and herbicides does have deleterious side effects. For example, in Switzerland, surface waters and springs have been contaminated in times of high rainfall by excessive amounts of fertilizers corresponding to 0.3-0.5 kg of phosphorous and 45 kg of nitrogen per hectare per year. This kind of thing occurs elsewhere as well, and it cannot but help transform—for all we know adversely—the environment in which living matter, including fish, otherwise thrive.

300. The dangers of the side effects of modern pesticides are also beginning to be appreciated and are already beginning to be guarded against in advanced countries. Except in high dosage, these substances act only on lower organisms, although some organophosphorous compounds are toxic to man and other vertebrates. Less selective agents may be toxic to soil bacteria, plankton, snails and fish. Chlorinated hydrocarbons, such as DDT, are toxic only in unusually high dosages but accumulate in fat and deposit in the liver and the central nervous system. Following surface application, pesticides enter the soil and seep into underground waters or become washed by rain into rivers, lakes and reservoirs. It is theoretically possible that in some situations in which non-selective chemical pesticides are used disruption of the ecological equilibrium could lead to the long-term suppression of useful animals and plants. These are dangers which only constant vigilance will avert.

301. Detergents are another modern chemical development whose use has had to be regulated, inasmuch as they have a direct short-term effect on certain types of natural food, such as daphniae and the algae which are eaten by fish. The first detergents which came on the market led to enormous quantities of foam on river, and this, in turn, reduced the supply of oxygen for organisms living in the water. They also damage the earth by affecting soil bacteria. Such detergents, which resist destruction even by the most modern water treatment methods, have all but disappeared from use and have been replaced by others, which can be almost completely destroyed by waste water treatment.

302. In the context of the possible long-term effects of chemical and bacteriological (biological) weapons, we have finally to note that towns and cities are growing all over the world and that in the developed countries conurbations (fusion of cities with loss of suburbs) have reached population levels approaching 50 million. Such great concentrations of people require very complicated arrangements for supply of food, water and other materials, transport and general administration. The use of chemical or bacteriological (biological) weapons against

cities would undoubtedly have an exceptionally severe disorganizing effect, and the full re-establishment of the services necessary for health, efficient government and the smooth operation of industry might take a very long time.

C. Possible long-term effects of chemical and bacteriological (biological) means of warfare on man and his environment

303. Chemical weapons, in addition to their highly toxic short-term effects, may also have a long-term effect on the environment in which they are disseminated. If used in very high concentration they might cause damage by polluting the air, by polluting the water supplies and by poisoning the soil.

304. Bacteriological (biological) weapons could be directed against man's sources of food through the spread of persistent plant diseases or of infectious animal diseases. There is also the possibility that new epidemic diseases could be introduced, or old ones reintroduced, which could result in deaths on the scale which characterized the mediaeval plagues.

1. Chemical weapons

305. There is no evidence that the chemical agents used in the First World War—chlorine, mustard, phosgene and tear-gas—had any untoward ecological consequences. As already observed, over 120,000 tons of these agents were used during that war, and in some areas which were attacked concentrations must have added up to hundreds of kilogrammes per hectare. These regions have long since returned to normal and fully productive use.

306. The organophosphorous, or nerve, agents have never been used in war, and no corresponding experience is available to help form a judgement about their possible long-term effects. But inasmuch as these agents are toxic to all forms of animal life, it is to be expected that if high concentrations were disseminated over large areas, and if certain species were virtually exterminated, the dynamic ecological equilibrium of the region might be changed.

307. On the other hand, there is no evidence to suggest that nerve agents affect food chains in the way that DDT and other pesticides of the chlorinated hydrocarbon type do. They hydrolyze in water, some of them slowly, so that there could be no long-term contamination of natural or artificial bodies of water.

308. The use of herbicides during the course of the Viet-Nam conflict has been reported extensively in news media and, to a lesser extent, in technical publications. The materials which have been used are 2,4-dichlorophenoxyacetic acid, 2,4,5-trichlorophenoxyacetic acid, cacodylic acid and picloram.

309. Between 1963 and 1968 these herbicides were used to clear forested areas for military purposes over some 9,100 km². This may be divided by forest type as shown in table 9.

TABLE 9. TYPE OF FOREST AND EXTENT AND AREA TREATED WITH HERBICIDES IN SOUTH VIET-NAM. 1963-1968

Type of forest	*Extent (km2)*	*Area treated (km2)*
Open forest (semi-deciduous)	50,150	8,140
Mangrove and other aquatic	4,800	960
Coniferous	1,250	0
TOTAL	56,200	9,100

310. South Viet-Nam is about 172,000 km² in area, of which about one third is forested. The area treated with herbicides up to the end of 1968 thus amounts to about 16 per cent of the forested area, or a little over 5 per cent of the total.

311. There is as yet no scientific evaluation of the extent of the long-term ecological changes resulting from these attacks. One estimate is that some mangrove forests may need twenty years to regenerate, and fears have been expressed about the future of the animal population they contain. Certain species of bird are known to have migrated from areas that have been attacked. On the other hand, there has been no decline in fish catches, and as fish are well up in the food chain, no serious damage would seem to have been done to the aquatic environment.

312. When a forest in a state of ecological equilibrium is destroyed by cutting, a secondary forest regenerates, which contains fewer species of plants and animals than were there originally, but larger numbers of those species which survive. If secondary forest is replaced by grassland, these changes are even more marked. If one or more of the animal species which increases in numbers is the host of an infection dangerous to man (a zoonosis), then the risk of human infection is greatly increased. This is exemplified by the history of scrub typhus in south-east Asia, where the species of rat which maintains the infection and the vector mite are much more numerous in secondary forest, and even more so in grassland, so increasing the risk of the disease being transmitted to people as forest is cleared.

313. In high rainfall areas, deforestation may also lead to serious erosion, and so to considerable agricultural losses. Deserts have been created in this way.

Against man

314. New natural foci, in which infection may persist for many years, may be established after an aerosol or other type of bacteriological (biological) attack. This possible danger can be appreciated when one recalls the epidemiological consequences of the accidental introduction of rabies and other veterinary infections (blue-tongue, African swine fever) into a number of countries. The spread of rabies in Europe following the Second World War, as a consequence of the disorganization caused by the war, shows how an epidemiologically complicated and medically dangerous situation can emerge even with an infection which had long been successfully controlled. In 1945 there were only three major foci of infection in Czechoslovakia. In the following years, foxes multiplied excessively because farms were left unworked, because of the increased number of many kinds of wild creatures and because of the discontinuation of systematic control. Foxes also came in from across frontiers, and the epizootic gradually worsened. In the period 1952-1966 a total of 888 foci were reported, 197 new ones in 1965 alone. Bringing the situation under control demanded extraordinary and prolonged efforts by the health service: in 1966 alone, 775,000 domestic animals were vaccinated in affected areas of the country. None the less, the disease has not yet been stamped out. Natural foci cannot be eliminated without organized and long-term international co-operation.

315. Arthropods (insects, ticks) also play an important part, along with other creatures, in the maintenance of pathogenic agents in natural foci. A man exposed to a natural focus risks infection, particularly from arthropods, which feed on more than one species of host. A bacteriological (biological) attack might lead to the creation of multiple and densely distributed foci of infection from which, if ecological conditions were favourable, natural foci might develop in regions where they had previously never existed or in areas from which they had been eliminated by effective public health measures.

316. On the other hand, the large-scale use of bacteriological (biological) weapons might reduce populations of susceptible wild species below the level at which they could continue to exist. The elimination of a species or group of species from an area would create in the ecological community an empty niche which might seriously disturb its equilibrium or which might be filled by another species more dangerous to man because it carried a zoonosis infection acquired either naturally or as a result of the attack. This would result in the establishment of a new natural focus of disease.

317. The gravity of these risks would depend on the extent to which the community of species in the country attacked contained animals which were not only susceptible to the infection but were living in so close a relationship to each other that the infection could

become established. For example, not all mosquito species can be infected with yellow fever virus, and if the disease is to become established, those which can become vectors must feed frequently on mammals, such as monkeys, which are also sufficiently susceptible to the infection. A natural focus of yellow fever is therefore very unlikely to become established in any area lacking an adequate population of suitable mosquitoes and monkeys.

318. Endemics or enzootics of diseases (i.e., infections spreading at a low rate, but indefinitely, in a human or animal population) could conceivably follow a large-scale attack, or might be started by a small-scale sabotage attack, for which purpose the range of possible agents would be much wider and might even include such chronic infections as malaria.

319. *Malaria* is a serious epidemic disease in a susceptible population, but it is difficult to envisage its possible employment as a bacteriological (biological) weapon, because of the complex life cycle of the parasite. Drug-resistant strains of malaria exist in, for example, areas of Asia and South America, and their possible extension to areas where mosquitoes capable of transmiting the disease already exist would greatly complicate public health measures and cause a more serious disease problem because of the difficulties of treatment.

320. *Yellow fever* is still enzootic in the tropical regions of Africa and America. Monkeys and other forest-dwelling primates, together with mosquitoes which transmit the virus, constitute natural foci and ensure survival of the virus between epidemics.

321. Importation of this disease is possible wherever a suitable environment and susceptible animal and mosquito hosts exist. This occurred naturally in 1960 when a previously uninfested area of Ethiopia was invaded by yellow fever and an epidemic resulted in about 15,000 deaths. Because of the inaccessibility of the area, some 8,000-9,000 people had died before the epidemic was recognized. The epidemic was extinguished, but it is likely that a permanent focus of yellow fever infection has been established in this area, previously free of the disease. It might be extremely serious if the virus were introduced into Asia or the Pacific islands where the disease appears never to have occurred but where local species of mosquito are known to be able to transmit it. Serious problems could also arise if the virus were introduced into the area of the United States where vector mosquitoes still exist and where millions of people live in an area of a few square kilometres.

322. Another consideration is the possible introduction of a new species of animal to an area to cause either long-term disease or economic problems. For example, mongooses were introduced many years ago to some Caribbean islands, and in one at least they have become a serious economic pest of the sugar crop and an important cause of rabies. The very large economic effect on the introduction of rabbits to Australia is well known. Certain mosquito species (a yellow fever

mosquito, *Aedes aegypti,* and a malaria mosquito *Anopheles gambiae*) have naturally spread to many areas of the world from their original home in Africa and have been responsible for serious disease problems in the areas that have been invaded. It is conceivable that in the war the introduction of such insects on a small scale might be tried for offensive purposes.

323. In addition to the development of new natural foci, another long-term hazard, but one which is very much more speculative than some of the possibilities mentioned above, is that of the establishment of new strains of organisms of altered immunological characteristics or increased virulence. This might occur if large numbers of people or other susceptible animal species became infected in an area through a bacteriological (biological) attack, thus providing opportunities for new organisms to arise naturally. The appearance from time to time of immunologically different forms of influenza shows the type of thing which might happen. Such altered forms of agents might cause more severe and perhaps more widespread epidemics than the original attack.

Against domestic animals

324. *Foot-and-mouth disease* is a highly infectious but largely non-fatal disease of cattle, swine and other cloven-footed animals. It is rarely transmitted from a diseased animal to man, and, when it is, the order is a trivial one.

325. The milk yield of diseased cows decreases sharply and does not reach its normal yield even after complete recovery. Losses range from 9 to 30 per cent of milk yield. In swine, loss from foot-and-mouth are estimated at 60-80 per cent among suckling pigs. Foot-and-mouth is endemic in many countries and breaks out from time to time even in countries which are normally free of the disease. Some countries let it run its course without taking any steps to control it; others try to control it by the use of vaccines; and some pursue a slaughter policy in which all affected animals and contacts are killed.

326. It is obvious that a large epizootic could constitute a very serious economic burden, for example, by bringing about a serious reduction in the supply of milk. It is in this context that foot-and-mouth disease could conceivably serve as a bacteriological (biological) weapon, especially since war conditions would greatly promote its spread. Efficient prevention is possible through active immunization, but the immunity is rather short-lived and annual vaccination is required.

327. *Brucellosis* is an example of chronic disease which could possibly result from bacteriological (biological) weapon attacks. There are three forms known, which attack cattle, swine and goats respectively. Any of these may be transmitted to man, in whom it causes a debilitating but rarely fatal disease lasting for four to six months or even longer. It is enzootic in most countries of the world, and an increased

incidence of the disease resulting from its use as a weapon could be dealt with, after the initial blow, in the same way as is the natural disease. But the cost of eliminating disease such as brucellosis from domestic animals is very high.

328. *Anthrax* was described in chapter II, and what concerns us here is that if large quantities of anthrax spores were disseminated in bacteriological (biological) weapons, thus contaminating the soil of large regions, danger to domestic animals and man might persist for a very long time. There is no known way by which areas could be rendered safe. The use of large quantities of anthrax as a weapon might therefore cause long-term environmental hazards.

Against crops

329. The *rust* fungus, as already noted, is one of the most damaging of natural pathogens which affect wheat crops. Each rust pustule produces 20,000 uredospores a day for two weeks, and there may be more than 100 pustules on a single infected leaf. The ripe uredospores are easily detached from the plant even by very weak air currents. The spores are then carried by the wind over distances of many hundreds of kilometres. It is estimated that the annual total world loss of wheat from rust is equivalent to about $500 million.

330. Weather plays a decisive role in the epiphytotic spreading of rust. Temperature influences the incubation period and the rate of uredospore germination. Germination and infection occur only when there is a water-saturated atmosphere for three or four hours. Thus, epiphytotic spread occurs when there are heavy dews and when the temperature is between 10° and 30° C. The principal means of prevention is to destroy the pathogen and to breed resistant species. Recently, ionizing radiation has been employed to develop resistant strains.

331. The cereal rusts die out during winter unless some other susceptible plant host, such as barberry, is present, and therefore their effect on crops would be limited to a single season. As they are capable of reducing man's food reserves considerably, rust spores could be extremely dangerous and efficient bacteriological (biological) weapons, especially if deployed selectively with due regard to climatic conditions. Artificial spreading of an epiphytotic would be difficult to recognize, and delivery of the pathogen to the target would be relatively simple.

332. Rust epiphytotics might have a very serious effect in densely populated developing countries, where the food supply might be reduced to such an extent that a human population already suffering from malnutrition might be driven to starvation, which, depending on the particular circumstances, might last a long time.

333. Another conceivable biological weapon, although neither a practical nor a bacteriological one, is the *potato beetle*. To use it for this purpose, the beetle would have to be produced in large numbers

and introduced, presumably clandestinely, into potato-growing regions at the correct time during maturation of the crop. In the course of spread the beetle first lives in small foci, which grow and increase until it becomes established over large territories. The beetle is capable of astonishing propagation: the progeny of a single beetle may amount to about 8,000 million in one and a half years.

334. Since beetles prefer to feed and lay their eggs in plants suffering from some viral disease, they and their larvae may help transmit the virus thereby increasing the damage they cause. The economic damage caused by the beetle varies with the season and the country affected, but it can destroy up to 80 per cent of the crop. Protection is difficult because it has not been possible to breed resistant potato species and the only means available at present is chemical protection.

335. Were the beetle ever to be used successfully for offensive purposes, it could clearly help bring about long-term damage because of the difficulty of control.

3. Genetic and carcinogenic changes

336. The possibility also exists that chemical and bacteriological (biological) weapons might cause genetic changes. Some chemicals are known to do this. LSD, for example, is known to cause genetic changes in human cells. Such genetic changes, whether induced by chemicals or viruses, might conceivably have a bearing on the development of cancer. A significantly increased incidence of cancer in the respiratory tract (mainly lung) has been reported recently among workers employed in the manufacture of mustard gas during the Second World War. No increased prevalence of cancer has been reported among mustard gas casualties of The First World War, although it is doubtful if available records would reveal it. However, most of these casualties were exposed for only short periods to the gas, whereas the workers were continuously exposed to small doses for months or years.

Chapter V

ECONOMIC AND SECURITY IMPLICATIONS OF THE DEVELOPMENT, ACQUISITION AND POSSIBLE USE OF CHEMICAL AND BACTERIOLOGICAL (BIOLOGICAL) WEAPONS AND SYSTEMS OF THEIR DELIVERY

A. General

337. Previous chapters have revealed the extent to which developments in chemical and biological science have magnified the potential risks associated with the concept of chemical or bacteriological (biological) warfare. These risks derive not only from the variety of possible agents which might be used but from the variety of their effects. The doubt that a chemical or bacteriological (biological) attack could be restricted to a given area means that casualties could occur well outside the target zone. Were these weapons used to blanket large areas and cities, they would cause massive loss of human life, affecting non-combatants in the same way as combatants, and, in this respect, they must clearly be classified as weapons of mass destruction. The report has also emphasized the great problems and cost which would be entailed in the provision of protection against chemical and bacteriological (biological) warfare. It is the purpose of this final chapter to explore in greater depth the economic and security implications of matters such as these.

B. Production

1. Chemical weapons

338. It has been estimated that during the course of the First World War, at a time when the chemical industry was in a relatively early stage of development, about 180,000 tons of chemical agents were produced, of which more than 120,000 tons were used in battle. With the rapid development of the industry since then, there has been an enormous growth in the potential capacity to produce chemical agents.

339. The scale, nature and cost of any programme for producing chemical weapons, and the time needed to implement it, would clearly be largely dependent on the scientific, technical and industrial potential of the country concerned. It would depend not only on the nature of the chemical industry itself and the availability of suitably trained en-

gineers and chemists but on the level of development of the chemical engineering industry and of the means of automating chemical processes, especially where the production of highly toxic chemical compounds is involved. Whatever the cost of developing a chemical or bacteriological (biological) capability, it needs to be realized that it would be a cost additional to, and not a substitute for, that of acquiring an armoury of conventional weapons. An army could be equipped with the latter without having any chemical or bacteriological (biological) weapons. But it could never rely on chemical or bacteriological (biological) weapons alone.

340. Today a large number of industrialized countries have the potential to produce a variety of chemical agents. Many of the intermediates required in their manufacture, and in some cases even the agents themselves, are widely used in peacetime. Such substances include, for example, phosgene, which some highly developed countries produce at the rate of more than 100,000 tons a year and which is commonly used as an intermediate in the manufacture of synthetic plastics, herbicides, insecticides, paints and pharmaceuticals. Another chemical agent hydrocyanic acid, is a valuable intermediate in the manufacture of a variety of synthetic organic products and is produced in even greater quantities. Ethylene-oxide, which is used in the manufacture of mustard gases, is also produced on a large scale in various countries. It is a valuable starting material in the production of a large number of important substances, such as detergents, disinfectants and wetting agents. The world production of ethylene-oxide and propylene-oxide is now well in excess of 2 million tons per year. Mustard gas and nitrogen mustard gases can be produced from ethylene-oxide by a relatively simple process. Two hundred and fifty thousand tons of ethylene-oxide would yield about 500,000 tons of mustard gas.

341. The production of highly toxic nerve agents, including organophosphorus compounds, presents problems which, because they are relatively difficult, could be very costly to overcome. To a certain extent this is because of the specialized safety precautions which would be needed to protect workers against these very poisonous substances, a need which, of course, applies to all chemical agents, especially to mustard gas. However, many intermediates used in the manufacture of nerve agents have a peacetime application: for example, dimethylphosphite, necessary for the production of Sarin, is used in the production of certain pesticides. But even leaving operating expenses aside, the approximate cost of acquiring one plant complex to produce munitions containing up to 10,000 tons of Sarin a year would be about $150 million. The cost, of course, would be considerably less if existing munitions could be charged with chemical agents.

342. A country which possessed a well-developed chemical industry could clearly adapt it to produce chemical agents. But were it to embark on such a step, it would be only the beginning. The establishment of a comprehensive chemical warfare capability would also involve special re-

search centres, experimental test grounds, bases, storage depots and arsenals. The development of sophisticated and comprehensive weapon systems for chemical or bacteriological (biological) warfare would be a very costly part of the whole process. None the less, the possibility that a peacetime chemical industry could be converted to work for military purposes, and of chemical products being used as weapons, increases the responsibility of Governments which are concerned to prevent chemical war from ever breaking out.

2. Bacteriological (biological) weapons

343. The microbiological expertise necessary to grow agents of bacteriological (biological) warfare exists to a large extent in many countries, inasmuch as the requirements are similar to those of a vaccine industry and, to a lesser extent, a fermentation industry. Apart from the combination of the highly developed technologies of these two industries, there remains only a need for some specialized knowledge, expertise and equipment to permit the safe handling of large quantities of bacteriological (biological) agents. Consequently, existing facilities in the fermentation, pharmaceutical and vaccine industries could be adapted for the production of bacteriological (biological) agents. But the technological complexities of producing bacteriological (biological) agents in dry powder form are very much greater than for wet spray systems. Moreover, it would be desirable to provide an effective vaccine with which to protect production staff. The technical difficulties would increase with the scale and complexity of the weapon systems that were being developed. But the fact remains that any industrially advanced country could acquire whatever capability it set out to achieve in this field.

344. The difficulty and cost of providing for the transport and storage of bacteriological (biological) weapons are considerable, since special storage conditions, e.g., refrigeration, and stringent safety and security precautions are essential. In addition, testing to determine the potential effectiveness of the material produced would require considerable and costly testing facilities both in the laboratory and in the field.

345. Despite the fact that the development and acquisition of a sophisticated armoury of chemical and bacteriological (biological) weapon system would prove very costly in resources and would be dependent on a sound industrial base and a body of well-trained scientists, any developing country could, in fact, acquire, in one way or another, a limited capability in this type of warfare—either a rudimentary capability which it developed itself or a more sophisticated one which it acquired from another country. Hence, the danger of the proliferation of this class of weapons applies as much to developing as it does to developed countries.

C. Delivery systems

346. Practically all types of explosive munitions (artillery shells, mines, guided and unguided rockets, serial bombs, landmines, grenades

etc.) can be adapted for the delivery of chemical agents. A modern bomber, for example, can carry about fifteen tons of toxic chemical agents, and it is estimated that only 250 tons of V-gas, an amount which could be delivered by no more than fifteen or sixteen aircraft, is enough to contaminate a great city with an area of 1,000 square kilometres and a population of from 7 to 10 million. Were such a population mainly in the open and unprotected, fatal casulaties might reach the level of 50 per cent.

347. Existing armaments which (with some modification) could be used to deliver agents in order to generate local outbreaks of disease could also contaminate large areas with pathogens. For example, a single aircraft could cover with a bacteriological (biological) agent an area of up to 100,000 square kilometres, although the area of effective dosage might be much smaller due to loss of the infectivity of the airborne agent.

348. Although in the developmnet and production costs of chemical and bacteriological (biological) agents might well be high, the cost of the complete weapon system (see chapter I) would be even greater. The cost of developing, procuring and operating a squadron of modern bombers far outweighs the cost of the bombs it could carry. However, for some purposes, an existing weapon system or a far less sophisticated means of disseminating might be used.

D. Protection

349. The measures which would be required to protect a population, its livestock and plants against chemical or bacteriological (biological) attack are immensely costly and complex (chapter I). At present, warning systems for the detection of aerosol clouds are fairly rudimentary. Systems for the detection of specific chemical and bacteriological (biological) agents might be devised, but again they are likely to prove very expensive, if indeed they are feasible.

350. With certain agents, contamination of the environment, for example of buildings and soil, could persist for several days or weeks. Throughout this period people would be exposed to the risk of contamination by contact and by inhalation. Protective clothing, even if adequately prefabricated and distributed or improvised, would make it to carry on with normal work. The prolonged wearing of respirators causes physiological difficulties, and it would prove necessary to provide communal shelters with air filtration and ventilations systems for civil populations. Shelters would be extremely costly to build and operate, and a programme for their construction would constitute a heavy burden on the economy.

351. Even if protective measures were provided against known agents, it is conceivable that new ones might be developed whose physical or chemical properties would dictate a need for new individual and communal protective equipment. This could constitute an even greater economic burden.

352. Defensive measures, especially against chemical agents, would also have to include the extremely laborious and expensive task of decontaminating large numbers of people, as well as equipment, weapons and other materials. This would mean setting up decontamination centres and training people in their use. Stocks of decontaminating agents and replacement clothing would also be required.

353. A very important part of a defense system against chemical or bacteriological (biological) weapons would be the means of very rapidly detecting an attack and identifying the specific agent used. Methods for doing this rapidly and accurately are still inadequate. Specific protection against bacteriological (biological) agents would necessitate the use of vaccines and, perhaps, antibiotics (see annex IV of chapter II). Vaccines vary in their effectiveness, even against naturally occurring infections, and even those which are highly effective in natural circumstances may not protect against bacteriological (biological) agents deliberately disseminated into the air and inhaled into the lungs. Antibiotics used prophylactically are a possible means of protection against bacteria and rickettsiae but not against viruses. But the large and complex problems of their use in large populations would be all but insuperable.

354. It would be extremely difficult to arrange for the medical treatment of a civilian population which had been attacked with chemical or bacteriological (biological) weapons. Mobile groups of specialists in infectious disease, of microbiologists and of well-trained epidemiologists would have to be organized to provide for early diagnosis and treatment, and a network of reserve hospitals and a massive supply of drugs would have to be prepared in advance. The maintenance of a stockpile of medical supplies is extremely costly. Many drugs, especially antibiotics, deteriorate in storage. Huge amounts would have to be discarded as useless from time to time, and the stock would have to be replenished periodically.

E. Cost to society

355. The extent to which the acquisition, storage, transport and testing of chemical and bacteriological (biological) munitions would constitute an economic burden would depend on the level of a country's industrial and military capability, although compared to nuclear weapons and advanced weapon systems in general, it might not seem excessive. But the task of organizing delivery systems and deployment on a large or sophisticated scale could well be economically disastrous for many countries. Moreover, the preparation of an armoury of chemical and bacteriological (biological) weapons would constitute a possible danger to people in the vicinity of production, storage and testing facilities.

356. Chemical and bacteriological (biological) attacks could be particularly dangerous in towns and densely populated areas, because of the close contacts between individuals and because of the centralized provision of services for every-day necessities and supply (services,

urban transport networks, trade etc.). The consequences might also be particularly serious in regions with a warm, moist climate, in low-lying areas and in areas with poorly developed medical facilities.

357. The technical and organizational complexity and the great financial cost of providing adequate protection for a population against attack by chemical and bacteriological (biological) agents have already been emphasized. The costs would be formidable by any standards. The construction of a system of fall-out shelters to protect only part of the population of one large and highly developed country against nuclear weapons has been estimated at no less than $5,000-$10,000 million. Such shelters could be modified, at a relatively modest additional cost, to provide protection against chemical and bacteriological (biological) weapons. To construct communal shelters for a corresponding part of the population against chemical and bacteriological (biological) weapons alone would cost much the same as protection against nuclear fall-out. If all other necessary related expenditures are considered—such as detection and warning systems, communications and medical aid—the total costs of civil defence against chemical and bacteriological (biological) agents would be greater than $15,000-$25,000 million for a developed country of 100-200 million people. But even if such a programme were ever planned and implemented, there could be no assurance that full protection could be achieved.

358. For whatever its cost, no shelter programme could provide absolute protection against attack by chemical or bacteriological (biological) agents. Protective measures would be effective only if there were adequate warning of an attack and if civil defence plans were brought into operation immediately and efficiently. However many shelters were available, the likelihood would be that large numbers of people would be affected to varying degrees and would be in urgent need of medical attention, and, once hostilities had ceased, that there would be large numbers of chronic sick and invalids, requiring care, support and treatment, and imposing a heavy burden on a society already disorganized by war.

359. It is almost impossible to conceive of the complexity of the arrangements which would be necessary to control the consequences of a large-scale bacteriological (biological) attack. Even in peacetime, the development of an epidemic of a highly contagious disease started by a few individual cases, introduced from abroad, necessitates, enormous material expenditure and the diversion of large numbers of medical personnel. Examples of widespread disruption due to a few smallpox contacts are given in chapter II. No estimates are given of the actual costs involved in dealing with these events, but in some cases they must have run into millions of dollars. Large-scale bacteriological (biological) attacks could thus have a serious impact on the entire economy of the target country, and, as is observed in chapter II, depending on the type of agent used, the disease might well spread to neighbouring countries.

360. Whatever might be done to try to save human beings, nothing significant could be done to protect crops, livestock, fodder and foodstuffs from a chemical and bacteriological (biological) weapons attack. Persistent chemical agents could constitute a particular danger to livestock.

361. Water in open reservoirs could be polluted as a result of deliberate attack, or perhaps accidentally, with chemical or bacteriological (biological) weapons. The water supply of large towns could become unusable, and rivers, lakes and streams might be temporarily contaminated.

362. Enormous damage could be done to the economy of a country whose agricultural crops were attacked with herbicides. For example, only 10-20 grammes per hectare of 2,4-D could render a cotton crop completely unproductive (see annex V). Fruit trees, grape vines and many other plants could also be destroyed. Mixtures of 2,4-D, of 2,4,-5-T and picloram are particularly potent. The chemical known as paraquat can destroy virtually all annual plants, including leguminous plants, rice, wheat and other cereals. Arsenic compounds dessicate the leaves of many crops and make them unusable as food. There are no means known at present of regenerating some of the plants which are affected by herbicides. Experience has shown, however, that in the case of some species either natural or artificial seeding can easily produce normal growth in the next growing season. But the destruction of fruit trees, vines and other plants, if achieved, could not be overcome for many years. For most practical purposes, it would be impossible to prevent the destruction of cultivated plants on which herbicides have been used, and, depending on a country's circumstances, widespread famine might follow.

363. If the induced disease were to spread, bacteriological (biological) weapons could affect even more extensive agricultural areas. The effect, however, would be more delayed and more specific to the crops affected. Annex V gives examples of the extent of the decrease in a wheat harvest and in a rice harvest affected by blast. The uredospores of the rust are easily transported by air currents, so that downwind sections would be affected by rust to a considerable distance, with a corresponding sharp reduction in the crop, while the upwind sections gave a good yield.

364. Over and above all these possible effects of chemical and bacteriological (biological) warfare on farm animals and crops is the possibility discussed in the previous chapter, of widespread ecological changes due to deleterious changes brought about in wild fauna and flora.

F. The relevance of chemical and bacteriological (biological) weapons to military and civil security

365. The comparison of the relative effectiveness of different classes of weapons is a hazardous and often futile exercise. The major

difficulty is that, from the military point of view, effectiveness cannot be measured just in terms of areas of devastation or of numbers of casualties. The final criterion would always be whether a specific military purpose had been more easily achieved with one rather than another set of weapons.

366. Clearly, from what has been said in the earlier chapters of this report, chemical weapons could be more effective than equivalent weights of high explosive when directed against densely populated targets. Similarly, so far as mass casualties are concerned, bacteriological (biological) weapons could, in some circumstances, have far more devastating effects than chemical weapons, and effects which might extend well beyond the zone of military operations.

367. From the military point of view, one essential difference between antipersonnel chemical and bacteriological (biological) weapons, on the one hand, and a conventional high-explosive weapon, on the other (including small arms and the whole range of projectiles), is that the area of the effects of the latter is more predictable. There are, of course, circumstances where, from the point of view of the individuals attacked, an incapacitating gas would be less damaging than high explosives. On the other hand, whereas military forces can, and do, rely entirely upon conventional weapons, no country, as already observed, could entrust its military security to an armoury of chemical and bacteriological (biological) weapons alone. The latter constitute only one band in the spectrum of weapons.

368. As previous chapters have also shown, neither the effectiveness nor the effects of chemical and bacteriological (biological) weapons can be predicted with assurance. Whatever military reasons might be advanced for the use of these weapons, and whatever their nature, whether incapacitating or lethal, there would be significant risk of escalation, not only in the use of the same type of weapon but of other categories of weapons systems, once their use had been initiated. Thus, chemical and bacteriological (biological) warfare could open the door to hostilities which could become less controlled, and less controllable, than any war in the past. Uncontrollable hostilities cannot be reconciled with the concept of military security.

369. Since some chemical and bacteriological (biological) weapons constitute a major threat to civilian populations and their food and water supplies, their use cannot be reconciled with general national and international security. Further, because of the scale and intensity of the potential effects of their use, they are considered as weapons of mass destruction. Their very existence thus contributes to international tension without compensating military advantages. They generate a sense of insecurity not only in countries with might be potentially belligerent but in those which are not. Neutral countries could be involved through the use of chemical and bacteriological (biological) weapons, especially those whose territories bordered on countries in-

volved in conflict in the course of which chemical and bacteriological (biological) casualties had been suffered by garrisons and civilians close to frontiers. The effects of certain bacteriological (biological) weapons used on a large scale might be particularly difficult to confine to the territory of a small country. Large-scale chemical and bacteriological (biological) agents and chemical agents might be used for acts of sabotage. Such events might occur as isolated acts, even carried out in defiance of the wishes of national leaders and military commanders. The continued existence and manufacture of chemical weapons anywhere may make such occurrences more likely.

370. Obviously, any extensive use of chemical weapons would be known to the country attacked. The source of the attack would probably also be known. On the other hand, it would be extremely difficult to detect isolated acts of sabotage in which bacteriological (biological) weapons were used, especially if the causative organism were already present in the attacked country. Because of the suspicions they would generate, acts of sabotage could thus provoke a conflict involving the widespread use of chemical and bacteriological (biological) weapons.

CONCLUSION

371. All weapons of war are destructive of human life, but chemical and bacteriological (biological) weapons stand in a class of their own as armaments which exercise their effects solely on living matter. The idea that bacteriological (biological) weapons could deliberately be used to spread disease generates a sense of horror. The fact that certain chemical and bacteriological (biological) agents are potentially unconfined in their effects, both in space and time, and that their large-scale use could conceivably have deleterious and irreversible effects on the balance of nature adds to the sense of insecurity and tension which the existence of this class of weapons engenders. Considerations such as these set them into a category of their own in relation to the continuing arms race.

372. The present inquiry has shown that the potential for developing an armoury of chemical and bacteriological (biological) weapons has grown considerably in recent years, not only in terms of the number of agents but in their toxicity and in the diversity of their effects. At one extreme, chemical agents exist and are being developed for use in the control of civil disorders; and others have been developed in order to increase the productivity of agriculture. But even though these substances may be less toxic than most other chemical agents, their ill-considered civil use or use for military purposes could turn out to be highly dangerous. At the other extreme, some potential chemical agents which could be used in weapons are among the most lethal poisons known. In certain circumstances the area over which some of them might exercise their effects could be strictly confined geographically. In other conditions some chemical and bacteriological (biological) weapons might spread their effects well beyond the target zone. No one could predict how long the effects of certain agents, particularly bacteriological (biological) weapons, might endure and spread and what changes they could generate.

373. Moreover, chemical and bacteriological (biological) weapons are not a cheap substitute for other kinds of weapon. They represent an additional drain on the national resources of those countries by which they are developed, produced and stockpiled. The cost, of course, cannot be estimated with precision; this would depend on the potential of a country's industry. To some the cost might be tolerable; to others it would be crippling, particularly, as has already been shown, when account is taken of the resources which would have to be diverted to the development of testing and delivery systems. And no system of defence,

even for the richest countries in the world, and whatever its cost, could be completely secure.

374. Because chemical and bacteriological (biological) weapons are unpredictable, ~~in varying degree,~~ ~~either~~ in the scale or duration of their effects, and because no certain defence can be planned against them, their universal elimination would not detract from any nation's security. Once any chemical or bacteriological (biological) weapon had been used in warfare, there would be a serious risk of escalation, both in the use of more dangerous weapons belonging to the same class and in the use of other weapons of mass destruction. In short, the development of a chemical or bacteriological (biological) armoury, and a defence, implies an economic burden without necessarily imparting any proportionate compensatory advantage to security. And, at the same time, it imposes a new and continuing threat to future international security.

375. The general conclusion of the report can thus be summed up in a few lines. Were these weapons ever to be used on a large scale in war, no one could predict how enduring the effects would be and how they would affect the structure of society and the environment in which we live. This overriding danger would apply as much to the country which initiated the use of these weapons as to the one which had been attacked, regardless of what protective measures it might have taken in parallel with its development of an offensive capability. A particular danger also derives from the fact that any country could develop or acquire, ~~in one way or another~~, a capability in this type of ~~warfare, despite the fact that this could prove costly~~. The danger of the proliferation of this class of weapons applies as much to the developing as ~~it does~~ to developed countries.

376. The momentum of the arms race would clearly decrease if the production of these weapons were effectively and unconditionally banned. Their use, which could cause an enormous loss of human life, has already been condemned and prohibited by international agreements, in particular the Geneva Protocol of 1925, and, more recently, in resolutions of the General Assembly of the United Nations. The prospects for general and complete disarmament under effective international control, and hence for peace throughout the world, would brighten significantly if the development, production and stockpiling of chemical and bacteriological (biological) agents intended for purposes of war were to end and if they were eliminated from all military arsenals.

377. If this were to happen, there would be a general lessening of international fear and tension. It is the hope of the authors that this report will contribute to public awareness of the profoundly dangerous results if these weapons were ever used and that an aroused public will demand and receive assurances that Governments are working for the earliest effective elimination of chemical and bacteriological (biological) weapons.

Annex I

EARLY WARNING SYSTEMS FOR AIRBORNE BACTERIOLOGICAL (BIOLOGICAL) AGENTS

An ideal automatic system for early warning against an attack with bacteriological (biological) agents would comprise the following components:

(*a*) A device to collect large volumes of air and concentrate the particulate matter obtained, in a small volume of fluid or on a small surface;

(*b*) A device to quantify and identify the collected material;

(*c*) A mechanism to assess the results and to initiate an alarm if necessary.

To collect and identify bacteriological (biological) agents and to initiate an alarm so that protective measures can be taken in sufficient time to be useful is extremely difficult. This is so because, first, identification of agents is generally time-consuming and, second, large and fluctuating quantities of bacteria and other organic materials exist in the atmosphere at all times. Thus, if pathogens from a cloud released by an aggressor were collected, the device would need not only to determine whether the quantity collected was significantly above the normal amounts that might occur, but what the agent was, or at least that, in the amount collected, it was highly dangerous to man.

At present, warning devices are available which are sensitive but non-specific, and these, unfortunately, would give an unacceptably high proportion of false alarms. Others are being developed which attempt to incorporate both rapid response with high specificity, but none to date is in the production stage. Research on this important problem is being continued, and some of the approaches and techniques that are being used in this study are listed below.

Classification of automated biodetection approaches[a]

General category	*Suggested approach*
Physical particle detection	Magnification
	Light scattering
	Volume displacement
Key biochemical components	Antigen detection by fluorescent labelling
	Dyes and staining
	Bioluminescence and fluorescence
	Optical activity
	Pyrolysis products detection
	ATP detection
	Proteins, nucleic acids, or others
Biological activity	Growth (increase in cell mass or numbers)
	CO_2 evolution
	Phosphatase activity
	Substrate change (pH, Eh, O_2 interchange)
	Pathogenic effects

[a] Adapted from V. W. Greene, "Biodetecting and Monitoring Instruments Open New Doors for Environmental Understanding", *Environmental Science Technology*, February 1968, pp. 104-112.

Annex II

CHEMICAL PROPERTIES, FORMULATIONS AND TOXICITIES OF LETHAL CHEMICAL AGENTS

(Excerpt from material supplied by the World Health Organization)

1		Sarin	VX	Hydrogen cyanide	Cyanogen chloride	Phosgene	Mustard gas	Botulinal toxin A
2		Lethal agent (nerve gas)	Lethal agent (nerve gas)	Lethal agent (blood gas)	Lethal agent (blood gas)	Lethal agent (lung irritant)	Lethal agent (vesicant)	Lethal agent
3		100%	1-5%	100%	6-7%	Hydrolysed	0.05%	Soluble
4		12,100 mg/m³	3-18 mg/m³	873,000 mg/m³	3,300,000 mg/m³	6,370,000 mg/m³	630 mg/m³	Negligible
5	(*a*)	Liquid	Liquid	Liquid	Solid	Liquid	Solid	Solid
5	(*b*)	Liquid	Liquid	Liquid	Vapour	Vapour	Liquid	Solid
6	(*a*)	1/4–1 hr	1-12 hrs	Few minutes	Few minutes	Few minutes	12-48 hrs	—
6	(*b*)	1/4–4 hrs	3-21 days	Few minutes	Few minutes	Few minutes	2-7 days	—
6	(*c*)	1–2 days	1-16 weeks	1-4 hrs	1/4-4 hrs	1/4-1 hr	2-8 weeks	—
7		>5 mg–min/m³	>0.5 mg–min/m³	>2,000 mg-min/m³	>7,000 mg-min/m³	>1,600 mg-min/m³	>100 mg-min/m³	0.001 mg (oral)
8		100 mg-min/m³	10 mg-min/m³	5,000 mg-min/m³	11,000 mg-min/m³	3,200 mg-min/m³	1,500 mg-min/m³	0.02 mg-min/m³
9		1,500 mg/man	6 mg/man	—	—	—	4,500 mg/man[a]	—

[a] A drop of mustard weighing a few mgs can produce a serious blister which will be incapacitating if it interferes with the normal activities of an individual.

Key to table:

1. Trivial name.
2. Military classification.
3. Approximate solubility in water at 20°C.
4. Volatility at 20°C.
5. Physical state: (*a*) at –10°C; (*b*) at 20°C.
6. Approximate duration of hazard (contact, or airborne following evaporation) to be expected from ground contamination: (*a*) 10°C, rainy, moderate wind; (*b*) 15°C, sunny, light breeze; (*c*) –10°C, sunny, no wind, settled snow.
7. Casualty producing dosages (lethal or significant incapacitating effects).
8. Estimated human respiratory LCt50 (mild activity: breathing rate *ca.* 15 litres/min.).
9. Estimated human percutaneous toxicity.

Annex III

TEAR AND HARASSING GASES

Three parameters will be used to qualify the effects of tear gases. These are defined as follows:

Threshold of irritation is the atmospheric concentration of the substance (in mg per m^3), which, in one minute of exposure, causes irritation.

Tolerance limit is the highest atmospheric concentration (in mg per m^3) which a test subject can tolerate during one minute of exposure.

Lethal index is a dosage, and thus the product of the concentration in the air (in mg per m^3) and the time of exposure (in minutes), which causes mortality. Data for various tear gases are given in the following table.

The data given under "Lethal index" are from animal experiments with various species.

Tear gas	*Threshold of irritation* (mg/m^3)	*Tolerance limit* (mg/m^3)	*Lethal index* $(mg.min./m^3)$
Adamside (DM)	0.1	2–5	15,000-30,000
Ethyl bromacetate	5	5–50	25 000
Bromacetone	1.5	10	30,000
ω-Chloracetophenone (CN)	0.3–1.5	5–15	8,500-25,000
Ortho-chlorbenzylidene malononitrile (CS)	0.05–0.1	1–5	40,000-75,000

Annex IV

SOME BIOLOGICAL AGENTS THAT MAY BE USED TO ATTACK MAN

Disease	*Infectivity*[a]	*Transmissibility*[b]	*Incubation period*[c]	*Duration of illness*[c]	*Mortality*[c]	*Antibiotic therapy*	*Vaccination*[d]
Viral							
Chikungunya fever	Probably high	None	2-6 d	2 weeks —a few months	Very low ($<$1%)	None	None
Dengue fever	High	None	5-8 d	a few days to weeks	Very low ($<$1%)	None	None
Eastern equine encephalitis	High	None	5-15 d	1-3 weeks	High ($>$60%)	None	Under development
Tick-borne encephalitis	ᵛigh	None	1-2 weeks	1 week to a few months	Variable up to 30%	None	Under development
Venezuelan equine encephalitis	High	None	2-5 days	3-10 days	Low ($<$1%)	None	Under development
Influenza	High	High	1-3 days	3-10 days	Usually low, except for complicated cases	None	Available
Yellow fever	High	None	3-6 days	1-2 weeks	High (up to 40%)	None	Available
Smallpox	High	High	7-16 days	12-24 days	Variable but usually high (up to 30%)	None	Available
Rickettsial							
Q-fever	High	none or negligible	10-21 days (sometimes shorter)	1-3 weeks	Low (usually $<$1%)	Effective	Under development
Psittacosis	High	Moderately high	4-15 days	1—several weeks	Moderately high	Effective	None
Rocky Mountain spotted fever	High	None	3-10 days	2 weeks to several months	Usually high (up to 80%)	Effective	Under development
Epidemic typhus	High	None	6-15 days	A few weeks to months	Variable but usually high (up to 70%)	Effective	Available

Bacterial							
Anthrax (pulmonary)	Moderately high	Negligible	1-5 days	3-5 days	Almost invariably fatal	Effective if given very early	Available
Brucellosis	High	None	1-3 weeks	Several weeks to months	Low (<25%)	Moderately effective	Under development
Cholera	Low	High	1-5 days	One to several weeks	Usually high (up to 80%)	Moderately effective	Available
Glanders	High	None	2-14 days	4-6 weeks	Almost invariably fatal	Little effective	None
Melioidosis	High	None	1-5 days	4-20 days	Almost 100% fatal	Moderately effective	None
Plague (pneumonic)	High	High	2-5 days	1-2 days	Almost 100% fatal	Moderately effective if given early	Available
Tularæmia	High	Negligible	1-10 days	Two to several weeks	Usually low sometimes high (up to 60%)	Effective	Available
Typhoid fever	Moderately high	Moderately high	1-3 weeks	A few to several weeks	Moderately high up to (10%)	Moderately effective	Available
Dysentery	High	High	1-3 days	A few days to weeks	Low to moderately high depending on strain	Effective	None
Fungal							
Coccidioidomycosis	High	None	1-3 weeks	A few weeks to months	Low	None	None

[a] *Infectivity*; indicates the potency of the parasite to penetrate and multiply in the host's organism, regardless of the clinical manifestation of illness. In fact, there are several agents by which the great majority of the exposed population will be infected without developing clinical symptoms.

[b] *Transmissibility*: refers to *direct* transmission from man to man without the intervention of any arthropod vector.

[c] The figures listed under *incubation period*, *duration of disease* and *mortality* are based on epidemiological data. They vary, according to variations in virulence and dose of the infecting agent, resistance of the host and many other factors. It also should be noted that if the agents conecrned were deliberately spread in massive concentrations as agents of warfare, *the incubation periods might be shorter and the resulting symptoms more serious*. As to *mortality*, this refers to the ratio between the number of fatalities to the number of *diseased* (not to that of *infected*) individuals, if no treatment is given.

[d] The availability of vaccines is no indication of their degree of effectiveness.

Annex V

ECONOMIC LOSS FROM POSSIBLE USE OF CHEMICAL AND BACTERIOLOGICAL (BIOLOGICAL) WEAPONS AGAINST CROPS

Table 1

ECONOMIC LOSS WHICH COULD RESULT FROM THE USE OF CHEMICAL WEAPONS DUE TO THE DESTRUCTION OF CROPS PER HECTARE OF LAND

Type of plant	*Average harvest (in tons per hectare)*	*Price of 1 ton in US dollars*	*Sum total of losses in US dollars per hectare*
Cotton	3	$600	$1,800
Rice	5	84	420
Wheat	3	69	207
Apple-tree	30	140[a]	8,400[a]

[a] Will not produce apples for two years.

Table 2

ECONOMIC LOSS DUE TO THE USE OF BACTERIOLOGICAL (BIOLOGICAL) WEAPONS AGAINST CROPS

Plant	*Type of agent*	*Losses*		*Loss in US dollars per hectare*
		%	*Tons per hectare*	
Wheat	Cereal rust (Puccinia graminis)	80	24	$165
Rice	Rice blast (Piricularia drizae)	70	35	294

Annex VI

PROTOCOL FOR THE PROHIBITION OF THE USE IN WAR OF ASPHYXIATING, POISONOUS OR OTHER GASES, AND OF BACTERIOLOGICAL METHODS OF WARFARE. SIGNED AT GENEVA, 17 JUNE 1925

The undersigned plenipotentiaries, in the name of their respective Governments:

WHEREAS the use in war of asphyxiating, poisonous or other gases, and of all analogous liquids, materials or devices, has been justly condemned by the general opinion of the civilized world;

WHEREAS the prohibition of such use has been declared in Treaties to which the majority of Powers of the world are Parties; and

To the end that this prohibition shall be universally accepted as a part of International Law, binding alike the conscience and the practice of nations;

DECLARE:

That the High Contracting Parties, so far as they are not already Parties to Treaties prohibiting such use, accept this prohibition, agree to extend this prohibition to the use of bacteriological methods of warfare and agree to be bound as between themselves according to the terms of this declaration.

The High Contracting Parties will exert every effort to induce other States to accede to the present Protocol. Such accession will be notified to the Government of the French Republic, and by the latter to all signatory and acceding Powers, and will take effect on the date of the notification by the Government of the French Republic.

The present Protocol, of which the French and English texts are both authentic, shall be ratified as soon as possible. It shall bear today's date.

The ratifications of the present Protocol shall be addressed to the Government of the French Republic, which will at once notify the deposit of such ratification to each of the signatory and acceding Powers.

The instruments of ratification of and accession to the present Protocol will remain deposited in the archives of the Government of the French Republic.

The present Protocol will come into force for each signatory Power as from the date of deposit of its ratification, and, from that moment, each Power will be bound as regards other Powers which have already deposited their ratifications.

IN WITNESS WHEREOF the Plenipotentiaries have signed the present Protocol.

DONE at Geneva in a single copy, the seventeenth day of June, One Thousand Nine Hundred and Twenty-Five.

Annex VII

GENERAL ASSEMBLY RESOLUTION 2162 B (XXI)

The General Assembly,

Guided by the principles of the Charter of the United Nations and of international law,

Considering that weapons of mass destruction constitute a danger to all mankind and are incompatible with the accepted norms of civilization,

Affirming that the strict observance of the rules of international law on the conduct of warfare is in the interest of maintaining these standards of civilization,

Recalling that the Geneva Protocol for the Prohibition of the Use in War of Asphyxiating, Poisonous or Other Gases, and of Bacteriological Methods of Warfare, of 17 June 1925, has been signed and adopted and is recognized by many States,

Noting that the Conference of the Eighteen-Nation Committee on Disarmament has the task of seeking an agreement on the cessation of the development and production of chemical and bacteriological weapons and other weapons of mass destruction, and on the elimination of all such weapons from national arsenals, as called for in the draft proposals on general and complete disarmament now before the Conference,

1. *Calls for* strict observance by all States of the principles and objectives of the Protocol for the Prohibition of the Use in War of Asphyxiating, Poisonous or Other Gases, and of Bacteriological Methods of Warfare, signed at Geneva on 17 June 1925, and condemns all actions contrary to those objectives;

2. *Invites* all States to accede to the Geneva Protocol of 17 June 1925.

1484th plenary meeting,
5 December 1966

Annex VIII

GENERAL ASSEMBLY RESOLUTION 2454 A (XXIII)

The General Assembly,

Reaffirming the recommendations of its resolution 2162 B (XXI) calling for strict observance by all States of the principles and objectives of the Protocol for the Prohibition of the Use in War of Asphyxiating, Poisonous or other Gases, and of Bacteriological Methods of Warfare signed at Geneva on 17 June 1925, condemning all actions contrary to those objectives and inviting all States to accede to that Protocol,

Considering that the possibility of the use of chemical and bacteriological weapons constitutes a serious threat to mankind,

Believing that the people of the world should be made aware of the consequences of the use of chemical and bacteriological weapons,

Having considered the report of the Eighteen-Nation Disarmament Committee which recommended that the Secretary-General appoint a group of experts to study the effects of the possible use of such weapons,

Noting the interest in a report on various aspects of the problem of chemical, bacteriological and other biological weapons which has been expressed by many Governments and the welcome given to the recommendation of the Eighteen-Nation Disarmament Committee by the Secretary-General in his Annual Report for 1967-68,

Believing that such a study would provide a valuable contribution to the consideration in the Eighteen-Nation Disarmament Committee of the problems connected with chemical and bacteriological weapons,

Recalling the value of the report of the Secretary-General on the effects of the possible use of nuclear weapons,

1. *Requests* the Secretary-General to prepare a concise report in accordance with the proposal in Part II of his Introduction to the Annual Report for 1967-68 and in accordance with the recommendation of the Eighteen-Nation Disarmament Committee contained in paragraph 26 of its report (document A/7189);

2. *Recommends* that the report be based on accessible material and prepared with the assistance of qualified consultant experts appointed by the Secretary-General, taking into account the views expressed and the suggestions made during the discussion of this item at the twenty-third session of the General Assembly;

3. *Calls upon* Governments, national and international scientific institutions and organizations to co-operate with the Secretary-General in the preparation of the report;

4. *Requests* that the report be transmitted to the Eighteen-Nation Disarmament Committee, the Security Council and the General Assembly at an early date, if possible by 1 July 1969, and to the Governments of Member States

in time to permit its consideration at the twenty-fourth session of the General Assembly;

5. *Recommends* that Governments give the report wide distribution in their respective languages, through various media of communication, so as to acquaint public opinion with its contents;

6. *Reiterates* its call for strict observance by all States of the principles and objectives of the Geneva Protocol of 17 June 1925 and invites all States to accede to that Protocol.

1750th plenary meeting,
20 December 1968

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