REVIEW CONFERENCE OF THE PARTIES TO THE CONVENTION ON THE PROHIBITION OF THE DEVELOPMENT, PRODUCTION AND STOCKPILING OF BACTERIOLOGICAL (BIOLOGICAL) AND TOXIN WEAPONS AND ON THEIR DESTRUCTION

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REPORT OF THE PREPARATORY COMMITTEE FOR THE REVIEW CONFERENCE OF THE PARTIES TO THE CONVENTION ON THE PROHIBITION OF THE DEVELOPMENT, PRODUCTION AND STOCKPILING OF BACTERIOLOGICAL (BIOLOGICAL) AND TOXIN WEAPONS AND ON THEIR DESTRUCTION

Note by the Secretariat

In paragraph 11 of the report of the Preparatory Committee for the Review Conference of the Parties to the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction (BWC/CONF.I/3), the Committee decided to request the Depositary Governments to prepare a background paper on new scientific and technological developments relevant to the Convention and to provide the paper to all States parties before the Review Conference.

In paragraph 12 of the report, the Committee also decided that the Secretary of the Committee would invite the comments of States parties on the background paper.

The background paper, submitted by the Depositary Governments to the Secretariat on 8 February, is reproduced in this document for consideration and comments by States parties to the Convention.

New scientific and technological developments relevant to the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction

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INTRODUCTION

1. Article XII of the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction, provides that:

> "Five years after the entry into force of this Convention, or earlier if it is requested by a majority of Parties to the Convention by submitting a proposal to this effect to the Depositary Governments, a conference of States Parties to the Convention shall be held at Geneva, Switzerland, to review the operation of the Convention, with a view to assuring that the purposes of the preamble and the provisions of the Convention, including the provisions concerning negotiations on chemical weapons, are being realized. Such review shall take into account any new scientific and technological developments relevant to the Convention." (Emphasis added.)

2. The Preparatory Committee for the Review Conference of the Parties to the Convention which met in Geneva, Switzerland in July 1979 decided to request the Depositary Governments to prepare a background paper on new scientific and technological developments relevant to the Convention.

3. The present review of new scientific and technological developments relevant to the Convention has been prepared by experts of the Depositary Governments in accordance with the recommendations of the Preparatory Committee.

4. The review reflects the new scientific and technological developments related to the Convention which have taken place since the preparation of the Convention and after its entry into force, bearing in mind that scientific and technological developments related to bacteriological (biological) and toxin weapons which had come into being during the previous period have already been summarized in a number of documents, in particular in the 1969 report of the Secretary-General entitled "Chemical and bacteriological (biological) weapons and the effects of their possible use", and in the 1970 report of a group of consultants to the World Health Organization entitled "Health aspects of chemical and biological weapons".

5. The review does not cover all new scientific and technological developments which could be regarded as relevant to the Convention to some degree. Rather, it deals only with major developments which appear to have a direct connexion with a review of the Convention's operation.

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I. RECOMBINANT DNA TECHNIQUES

1. Recent developments in molecular biology have provided powerful techniques for manipulation of the deoxyribonucleic acid (DNA) molecules which form the genetic material of an organism. Collectively these techniques are called "recombinant DNA techniques". They have already been developed and successfully applied in a number of countries.

2. In the discussion which follows, the term "recombinant DNA techniques" refers to the newly developed methods whereby hybrid DNA molecules may first be assembled (recombined) in a directed manner outside living cells in order to (a) produce quantities of specific DNA molecules, proteins or other desired products encoded by the recombinant DNA or (b) impart altered characteristics to the organism. Other techniques of genetic modification and selection of micro-organisms, not involving recombinant DNA molecules, will be referred to as classical genetic techniques.

Basis for recombinant DNA techniques

3. Five major advances have facilitated the development of recombinant DNA techniques:

(a) Discovery of means for the cleavage of DNA in a very specific and highly reproducible manner;

(b) Development of methods for "in vitro" chemical synthesis of medium-length nucleic acid molecules. If the primary structure of a small or medium-length peptide is known, an investigator may be able to synthesize (and manipulate) the nucleic acid (gene) which codes for it, rather than isolating the gene from a living organism;

(c) Development of simple and generally applicable methods for the joining of DNA molecules. The molecules joined may be obtained from diverse organisms and through chemical synthesis;

(d) Development of methods which allow recombinant DNA molecules so produced to be introduced into various organisms, including higher organisms. The infectivity of naked nucleic acids is generally low since they are rapidly degraded by enzymes and are not readily taken up by cells. However, plasmids (nucleic acids which replicate in a cell independently from the nucleic acids of the chromosomes) are taken up more rapidly. By incorporating a recombinant DNA molecule into a plasmid, this characteristic can be exploited to transfer bybrid nucleic acids into host bacteria. Another technique is to incorporate the recombinant DNA molecule in a virus which is able to enter the cell in question. The bacteriophage lambda has been used, for example, to transfer recombinant DNA segments into the bacterium E.coli. It has been demonstrated that the virus SV40, which occurs in monkeys, can transfer recombinant DNA segments into certain human and other mammalian cells. A third, much less well-developed, technique is to enclose the nucleic acid in a lipoprotein or other envelope which will protect it from degradation and facilitate entry into cells; and

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(e) Discovery of methods for selecting clones of a desired kind of recombinant DNA in cells or viruses. This allows production of the recombinant DNA in quantity.

4. Using recombinant DNA techniques it appears possible to make specific changes in properties of micro-organisms such as nutrient requirements, resistance to antibacterial drugs, ability to produce a variety of compounds and ability to modify substances present in the culture medium. Important applications are already foreseen in medicine, agriculture, and industry. Examples are: the production of medically valuable products, such as insulin, growth hormone and angiotensin; the development of bacteria capable of carrying out industrial fermentation processes with enhanced efficiency; and the modification of plant-microbial relationships to give nitrogen-fixing ability to crop plants which do not now possess it.

Comparison with classical genetic techniques

5. It should be emphasized that modifying an organism by recombinant DNA techniques is similar in effect to modifying it by classical genetic techniques. Such methods include selection of spontaneously occurring genetic variants or those induced by irradiation, use of mutagens, or various forms of genetic recombination antedating recombinant DNA techniques, such as sexual and parasexual crossing, transduction with viruses and transformation with free DNA. Moreover, genetic exchange involving DNA molecules occurs in nature and has been instrumental in evolution, as in the case of natural pathogens. Consequently, even though more efficient and more specific than classical genetic techniques, recombinant DNA techniques are similar in principle. Recombinant DNA techniques do, however, permit the transfer of genetic material between widely divergent species; classical genetic techniques generally require considerable homology between the donor and recipient for genetic transfer to be possible.

Relationship to biological and toxin weapons

6. From a technical standpoint, recombinant DNA techniques could be used in an attempt to develop micro-organisms or toxins as warfare agents. However, now and for the foreseeable future, development and production of fundamentally new agents or toxins would present a problem of insurmountable complexity. Furthermore, the incentives for such an undertaking are not great. Naturally-occurring, disease-producing micro-organisms and toxins already span an exceedingly broad range, from some which are extraordinarily deadly to others usually producing only temporary illness.

7. Rather, recombinant DNA techniques might be used to modify the characteristics of an existing organism to increase its potential as a biological warfare agent or its ability to produce a toxin. For example, efforts might be made to: (a) convert a non-pathogenic micro-organism into a pathogenic one by giving it the ability to produce a highly lethal toxin; (b) change the antigenic structure of a highly pathogenic micro-organism, thus allowing it to overcome

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human immunity; (c) make a micro-organism resistant to the antibiotics normally used against it; or (d) make a micro-organism easier to produce or store. In the past, such efforts would have used the techniques of classical genetics alone.

8. While recombinant DNA techniques could offer a more efficient method for such genetic manipulations in certain cases, efforts to develop "improved" agents for biological or toxin warfare would not necessarily be successful. These methods still do not permit the characteristics of a micro-organism to be engineered to order. While some traits, such as drug resistance, can already be modified without great difficulty by both classical genetic and recombinant DNA techniques, many important characteristics of a micro-organism are the result of highly complex and poorly understood interactions controlled by widely separated genes. Such traits would not be easily susceptible to purposeful manipulation through simple changes in DNA sequences.

9. Furthermore, it should be noted that use of recombinant DNA techniques in development of biological or toxin warfare agents would not help to reduce the formidable safety requirements for any bacteriological weapon development activity involving pathogenic agents.

10. The discussion above leads to the following conclusions:

(a) All substances which could be developed or fabricated using recombinant DNA techniques would be covered by the formulation "microbial or other biological agents, or toxins whatever their origin or method of production" used in article I of the Convention, and therefore the emergence of these techniques does not alter the effects of the Convention; and

(b) Although recombinant DNA techniques could facilitate genetic manipulation of micro-organisms for biological or toxin warfare purposes, the resulting agents are unlikely to have advantages over known natural agents sufficient to provide compelling new motives for illegal production or military use in the foreseeable future. None the less, developments in the ability to manipulate genetic material intentionally should be followed closely and periodically re-evaluated.

II. NEW INFECTIOUS DISEASES

1. The years between 1967 and 1976 saw the appearance of four previously unknown and severe infectious diseases; the four diseases are Marburg disease, Ebola, Lassa fever and Legionnaire's disease. This paper describes these four diseases and discusses their possible biological warfare significance. It is implicit that the micro-organisms responsible for these, and any other new infectious diseases, are embraced by the Convention.

Marburg disease (green monkey disease; vervet monkey disease)

2. In 1967 there were 31 cases of a new virus disease in the Federal Republic of Germany and Yugoslavia, traced to the direct contact of laboratory worker with blood or tissue from vervet monkeys trapped in Africa. In 1975 a small number of cases appeared in South Africa.

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3. The incubation period ranges from 4 to 9 days, followed by the sudden onset of the disease; the case fatality rate is 29 per cent. Convalescence is prolonged for 3 to 4 weeks.

4. Laboratory confirmation of diagnosis, with its attendant safety precautions, requires special facilities and explicit knowledge, probably only available in very few nations. Treatment is supportive; no specific prophylaxis or therapy is available. The mechanism whereby man becomes infected is not clear, though close contact with infectious material or patients is clearly hazardous; the possibility of airborne infection exists. Whilst it has been found that monkeys are not the natural reservoir of this virus in Africa, little further information has been recorded and there have been no further outbreaks.

Ebola

5. Outbreaks of a haemorrhagic fever resembling Marburg disease occurred in Sudan and Zaire in 1976, caused by a virus morphologically similar to the Marburg virus but serologically quite distinct: this new agent was designated Ebola.

6. In 1976 Ebola produced over 500 cases with 350 deaths in the Sudan; 76 hospital staff were affected and 41 died. Two hospitals were brought to a standstill. As with Marburg the spread of infection seemed to depend on person-to-person contact or the handling of infectious material; the pattern of infection again emphasized the high susceptibility of man. Treatment was essentially supportive; attempts to apply barrier-nursing and quarantine failed in African hospitals, where there was little or no experience of sucy methods. However, in October 1979, a second, smaller outbreak occurred in southern Sudan, producing 33 confirmed cases with 22 deaths. As with Marburg disease, the origins of the virus remain obscure; no natural reservoir of the virus was detected.

Lassa Fever

7. Since 1969 four outbreaks of another new infectious disease appeared in Africa. The incubation period was between 3 and 16 days; the severity of the disease was emphasized by a high case fatality rate of 36 to 37 per cent and high infectivity. Convalescence was generally over some 2 to 4 weeks. Once again a considerable risk to hospital and laboratory staff was apparent; by 1974 20 medical workers had contracted Lassa fever and 9 of these had died.

8. A new member of the arena group of viruses, related to lymphocytic choriomeningitis virus and to two South American haemorrhagic fevers was revealed as the cause. Subsequently a common rodent in African villages, the multimammate rat, was found to be the most likely source of infection. It seems likely that the multimammate rats are chronic carriers of the virus which is excreted in their urine. Poor living conditions enhance rat-to-man contact and though the explicit modes of infection are not clear, mechanical or airborne spread of the virus seems likely. There is no specific prophylaxis or therapy, medical care is essentially supportive. This disease appears to be endemic in some parts of Africa and new cases are being seen frequently in Sierra Leone.

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Legionnaire's disease (Veteran's disease; Philadelphia respiratory disease)

9. In 1976 over 100 cases of an unusual pneumonia-like disease arose in those who had attended a convention in Philadelphia; 29 people died. All facts pointed to a common disease-producing microbial or toxic chemical source within or in the immediate vicinity of one hotel. Initially, since intensive investigation failed to isolate a micro-organism, a toxic chemical cause seemed likely. However, much later a small bacterium whose fastidious cultural needs had prevented initial recognition, was shown to be the causative micro-organism. Surveys showed that this disease had occurred previously in minor outbreaks in the United States of America and the United Kingdom, though no cause had been identified at that time.

10. After an incubation period of about seven days an influenza-like condition leads to pneumonia resembling that produced by several other infectious agents. The case fatality rate was about 23 per cent and recovery was slow. Antibiotic therapy is effective, but no specific prophylaxis is available.

11. Whilst the severity of legionnaire's disease is rather less than that of the other new diseases described here, its impact in the United States of America was considerable. The initial failure to determine a cause and the nature of the main outbreak combined to raise the possibility of a deliberate sabotage or terrorist attack.

12. Subsequent investigations support the possibility of an airborne mode of infection; support for this hypothesis comes from the isolation of the causative micro-organism from air-conditioner water tanks.

Discussion and findings

13. In view of the recent discovery of these diseases it is only pertinent to attempt an assessment of their potential as biological warfare agents, by reference to the basic characteristics required of such agents. Since there is general acceptance that the most militarily efficient method of biological warfare is airborne attack by agent aerosols, discussion is restricted to consideration of such use. Generally such an assessment would be based on the following factors:

(a) Capacity for large scale production and munition filling;

(b) Ease of dissemination and adequate stability;

(c) Infectivity and susceptibility;

(d) Casualty-producing efficiency for lethal or incapacitating effect;

(e) Transmissability and epidemic potential;

(f) Availability of prophylaxis and therapy;

(g) Retroactive, ecological and long-term effects.

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14. In fact, relatively little information on such factors for any of the four new disease agents exists. An assessment can only be based on published research which has been directed to:

(a) The development of laboratory diagnostic methods,

(b) The pathology of the disease,

(c) The taxonomy of the agents,

(d) Their general epidemiology, and

(e) Research and development related to effective medical care.

Little of this research has produced data relevant to an understanding of their potential as biological warfare agents.

15. On this unsatisfactory basis only a few cautious assessments can be made.

(a) On the basis of published information, no nation has the current ability to use the agents of these diseases in biological warfare;

(b) Knowledge of these agents is far below that required for fundamental assessment of suitability as biological warfare agents. Such knowledge is not likely to increase rapidly through necessary research on public health aspects;

(c) It is clear that the agents are highly infectious and there are faint indications of the susceptibility of man to aerosol infection. On the other hand, the great epidemic potential of the three virus diseases would diminish acceptance of their value in biological warfare, since uncontrollability of effects is usually regarded as a disadvantage. Further, they probably have no special advantages as biological warfare agents; other well-characterized micro-organisms with biological warfare potential abound.

16. Consequently, it is doubted that there are any current technical reasons for regarding these diseases as posing a new biological warfare threat. The agents of these diseases are covered by language of the Convention, as are any other new disease agents.

17. In addition to analysing the biological warfare significance of new infectious diseases, it may be useful in the future to evaluate the implications of eradication of smallpox and other infectious diseases. Mass vaccination against smallpox is no longer practised in a number of countries, which could ultimately result in widespread vulnerability to use of variola (smallpox) virus as a biological warfare agent. Similar vulnerabilities could result if other infectious diseases, such as plague or cholera, are finally eradicated.

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III. CHEMICAL SYNTHESIS OF TOXINS

1. Toxins are generally obtained from living organisms. However, during negotiation of the Convention, it was pointed out that in time chemical synthesis of toxins would be possible.

2. The attached table illustrates the current possibilities for chemical synthesis of toxins which, because of their high toxicity, might be regarded as having potential military significance. It can be seen that partial or total synthesis has been achieved since the Convention was negotiated for all of the low molecular weight compounds listed. In addition to the synthesis of low molecular weight, non-protein toxins, synthesis of the polypeptide cobrotoxin, which has a molecular weight an order of magnitude higher, has been reported.

3. The high molecular weight toxins present problems of structure determination and synthesis that have not yet been solved. Again, however, it can be seen from the table that some information has already been acquired. In time it will probably be possible to synthesize any toxin, no matter how large or complex.

4. The ability to synthesize toxins also implies the ability to synthesize compounds which are closely related and possess comparable (or greater) toxicity but are not found in nature.

5. It is important to note that from a technical standpoint advances in chemical syntheses of toxins currently appear unlikely to facilitate production of toxins in militarily significant quantities. The syntheses reported in the table are technically very difficult and result in only very small amounts of product. It would be easier to obtain the toxin from its natural source.

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TABLE

Examples of toxins and some of their properties

Toxin	LD_{50}, mouse, ug/kg bodyweight	Biological origin	Molecular weight	Chemical synthesis
Botulinum toxin A	0.001-0.00003	bacteria	900 000	
Tetanus toxin	0.002-0.0001	bacteria	68 000	
Staphylococcal enterotoxin B	0.1 (ED_{50} monkey)	bacteria	35 000	Amino-acid sequence reported 1970.
palytoxin	0.15	salt-water invertebrate	2 531	Partial structure determination reported 1978.
Ricin	0.6 (dog)	plant	80 000	
Batrachotoxin	2	frog	399	Formal total synthesis reported 1973.
Tetrodotoxin	8	fish, newt	319	Total synthesis reported 1972.
Saxitoxin	9	dinoflagellate	370	Total synthesis reported 1977.
Cobratoxin	50	snake	6 800	Synthetic attempt reported 1974.
Convallatoxin	80 (cat)	plant	500	Partial synthesis reported 1950; patented 1971.

For comparison, two synthetic compounds are included:

Sarin	100		140
Mustard Gas	8 600		159

Note: Based on document CCD/333, 6 July 1971.

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IV. THE INDUSTRIAL USE OF FERMENTATION TECHNIQUES

Introduction

1. Industrial microbiology had a considerable upsurge during the 1940s and 1950s with the rapid development of antibiotics. Previously the industrial use of fermentation techniques was limited to the ancient arts of brewing, wine making and to sections of the food industry. In recent years there has been a continual rapid expansion of the industry with an almost explosive increase in the availability of microbial products and the means of exploiting micro-organisms.

2. It is impossible to list here all the products of industrial microbiology or their uses but they can be grouped as follows:

Alcohols and alcoholic beverages

Antibiotics for medicine, veterinary use and as livestock fodder additives

Vaccines, diagnostic sera and allied products

Enzymes for a wide range of uses in food technology, industry, medicine and research

Hormones

Vitamins

Single-cell protein (SCP); microbial biomass containing 50 to 70 per cent protein for use in livestock fodder and human foodstuffs

Amino-acids for fodder additives

Sugar substitutes

Fertilizers

Solvents, fats and other basics for chemical industry

Micro-organisms are also now used for the biological control of fungal and insect pests of crops, for rodent pest control and in leaching metals from ores.

Experimental studies

3. Research and development (R and D) in industrial microbiology during the last decade has been pursued by developed nations; subjects which have received considerable attention are:

Large batch-culture vessels of up to 600 m^3 capacity have been developed and it is likely that 1200 m^3 vessels will be constructed. Continuous-culture plants with 100,000 tons/year output have been built.

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Developments in fermentation vessel design with emphasis on highly efficient aeration with low foaming and on anerobic (oxygen-free) growth.

Computer control of large-scale batch and continuous-culture processes.

Gamma-radiation sterilisation of nutrient feedstocks.

Spray-drying and milling of live micro-organisms and of microbial products.

Stabilization of live micro-organisms and microbial products for storage.

The use of natural or waste substrates to replace expensive nutrients for microbial growth, such as petrochemicals, natural gas, spent liquor from paper and wood processing, raw vegetable and timber wastes, peat and coal.

Studies on large-scale tissue cell culture and the large-scale growth, separation and purification of viruses.

Studies on the mathematics and biochemistry of microbial growth.

Increasing interest in recombinant DNA techniques (genetic engineering) to develop novel micro-organisms with industrially significant properties.

National capabilities

4. In view of the interest shown in many countries, national capabilities for industrial application of fermentation techniques have been increasing rapidly. However, the rate of advance has varied widely. National capabilities range from the non-existent to sophisticated industries with large numbers of facilities.

5. Even in developed nations considerable differences exist; many such nations possess antibiotic and vaccine plants but not plants for single-cell protein or amino-acids, or plants capable of producing a wide range of products. National domestic and exporting economics largely determine the extent of development. In relation to some products, whilst a large scale production capability may not exist, there may be considerable expertise, with export of plant and licensing of processes.

6. One of the most significant recent developments in this field has been the large-scale production of single-cell protein. This particular process also is a good example for illustrating the widely differing national capabilities for large-scale production of micro-organisms. Despite considerable investment in R and D and plant, single-cell protein has had an inauspicious history in several nations. The reasons for this are complex; differing national needs in the domestic and export economy, differing feedstock availability, requirements and costs, political, environmental and industrial pressures have combined to prevent or constrain large-scale production in several countries. While there are pilot plants in a number of developed countries, only a few countries possess large-scale plants. Annual national production capabilities range up to the million-ton level.

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Findings

7. Much of the rapid expansion of industrial use of fermentation techniques for peaceful purposes has occurred since the Convention came into force in 1975. Implementation of the Convention's provisions has not hindered the exploitation of these techniques. In view of the considerable potential benefit for peaceful purposes, further rapid development in this field can be expected.

8. Generally production plants for civil use will be specifically designed for a particular process. In most cases it would be difficult to use these plants for biological weapons purposes without considerable conversion, both in the process itself and in associated safety and other special technical equipment.

9. In a general sense, industrial use of fermentation technology could provide a base of trained personnel and experience which would increase the potential for developing and producing biological or toxin weapons. This situation however, is not unique. Civil capabilities in many other fields could be diverted to military ends. From a scientific and technological standpoint, growing industrial use of fermentation techniques does not appear to substantially alter capabilities or incentives for biological or toxin warfare.

V. MICROBIAL CONTROL OF PESTS

1. Recent years have brought an increasing awareness of the actual or potential harmful effects of synthetic chemical pesticides on man, an awareness of the remarkable ability of the target pests to develop resistance, and appreciation of the disadvantages of non-specific chemical agents.

2. These facts led to the urgent investigation of alternative microbiological methods for combatting pests; some such methods have been in use since the early 1900s but until the last few years investment in such activity had been small.

3. Microbiological methods involve the large-scale production of certain live micro-organisms or their extractable toxins, the formulation of a liquid or powder product and dissemination of the product by vehicle or aircraft-borne sprays (or in rodent control, the use of ground bait) over crops or forests. With live microbial agents death of the insect or rodent occurs through infection; with microbial toxins death is produced by toxic effects. In some basic respects the whole sequence resembles biological warfare.

4. The bacterial and viral agents used for pest control do not affect man (nor indeed, other non-susceptible species); their effect is selective. One bacterial species (Salmonella enteriditis) used in rodent control is, however, a facultative pathogen for man and precautions are necessary for the avoidance of infection. Safety constraints may be necessary for a few other facultative pathogenic bacteria.

5. There are considerable national differences in interest, research and development, and capability, but the last few years have seen a remarkable increase

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in such interest. Microbial methods do not provide a complete solution to the problems of pest control; they are slower acting, more expensive and probably more susceptible to the effects of weather conditions.

6. A few examples show how viral, bacterial and fungal agents are produced and used.

Viruses

Nuclear polyhedrosis and granulosis viruses; produced on a large scale by a few nations, using mass rearing of insect hosts. The viruses extracted at a concentration of 12 x 10^6 infective units/ml are sprayed by aircraft. Viral insecticides are more expensive to produce than bacterial insecticides but they have the possible advantage of high target-specificity.

Bacteria

Bacillus thuringiensis: produced by several nations on a multi-tonne basis in deep-aerated vessels. The final product contains about 3 x 10^{10} bacterial spores/g. and is stable for 2 to 3 years. Disseminated by aircraft spray as liquid or powder aerosol, the bacterium is highly valued for controlling a wide variety of insect pests.

Bacillus popillae: is another agent produced and used in much the same way as Bacillus thuringiensis for controlling Japanese beetle larvae.

Pseudomonas aeruginosa (and Pl. fluorescens) and Chromobacterium prodigiosum: produced and used in a few countries for dissemination by aircraft spray on reservoirs (at 10 x 10^6 organisms/cm^2 water surface) in mosquito larvae control. These agents are, however, facultative pathogens for man.

Fungi

Various species such as Trichoderma, Sporotrichum, Beauveria and Cuelomomyces are produced on a multi-tonne basis by several nations. They are disseminated by aircraft spray to infect insect pests and sometimes to attack other fungal diseases of crops. Additionally, a number of other microbial agents are currently being studied, or evaluated in field trails.

Findings

7. None of the microbial agents studied or used in pest control have potential for diversion to biological weapons purposes; they are relatively specific in their host selection. For a variety of technical reasons, those bacterial agents which are facultative pathogens for man are unlikely to be acceptable as militarily effective biological warfare agents. There are dissimilarities, and to a certain extent similarities, between the peaceful activities directed to pest control by microbes and those relevant to development and production of biological warfare agents. However, misuse of both expertise and facilities is adequately covered by

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the terms of the Convention and this risk appears to be outweighed by the significant peaceful potential in this method of pest control.

VI. SCIENTIFIC AND TECHNOLOGICAL FINDINGS

1. The rapid pace of scientific and technological developments in areas closely related to the Convention demonstrates that the implementation of the Convention's provisions has not hindered activities for peaceful purposes.

2. Although new scientific and technological developments could permit the development of microbial or other biological agents or toxins with enhanced military utility, these new agents are unlikely to improve upon known agents to the extent of providing compelling advantages for illegal production or military use in the foreseeable future.

3. The language of the Convention fully covers all agents which could result from application of recombinant DNA techniques or of any of the other new developments discussed in this paper. There are no grounds whatsoever to place such agents in any other category of weapons of mass destruction. Scientific and technological developments have not created ambiguities or fundamentally new possibilities which could be exploited to violate covertly or bypass the Convention. These findings follow from the broad language of the Convention itself and are not dependent upon detailed technical factors.

4. In a general sense, improvement of civil capabilities, especially in the microbiological industry, could provide a base of trained personnel and experience which would increase the potential for developing and producing biological or toxin weapons. This situation, however, is not unique. Civil capabilities in many other fields could also be diverted to military ends. From a scientific and technological standpoint, the developments discussed in this paper, which are directed to peaceful purposes, do not appear to alter substantially capabilities or incentives for the development or production of biological or toxin weapons.
