INTRODUCTION

Definitions

Biological Agent (BA). The NATO definition of a Biological Agent is: a microorganism (or a toxin derived from it) which causes disease in man, plants or animals or which causes the deterioration of material. This document is primarily concerned with BA that have effects on humans.

Biological Defence (BD). Biological defence comprises the methods, plans and procedures involved in establishing and executing defensive measures against biological attack. (Procedures, equipment and training would be encompassed in this definition.)

Biological Warfare (BW). Biological warfare is the employment of BA to produce casualties in man or animals and damage to plants or material. The NATO definition then continues, to include, "or defence against such employment." BA that have potential to be used within BW are termed BW agents.

Biological Weapon. A biological weapon is an item of material, which projects, disperses, or disseminates a biological agent; including for example, arthropod vectors.

Toxin. A poisonous substance produced or derived from living plants, animals, or microorganisms; some toxins may also be produced or altered by chemical means. Compared with microorganisms, toxins have a relatively simple biochemical composition and are not able to reproduce themselves.

HISTORICAL

Historical Perspective

Throughout history, infectious diseases contracted naturally have had a significant impact on military operations. Furthermore the effect of disease introduced to naïve populations was clearly demonstrated by the spread of smallpox in the Americas after the arrival of Europeans and illustrates the potential impact of the deliberate use of BA. The intentional dissemination of disease adds a new dimension to threats that are posed by infectious and toxic agents traditionally transmitted only by natural routes. BA reportedly have been employed to a limited extent during recent military conflicts (for example, dispersion of plague bacilli during World War 2) and by terrorists (for example, dispersion of anthrax spores by mail in the US during 2001) however, their use actually dates from antiquity.

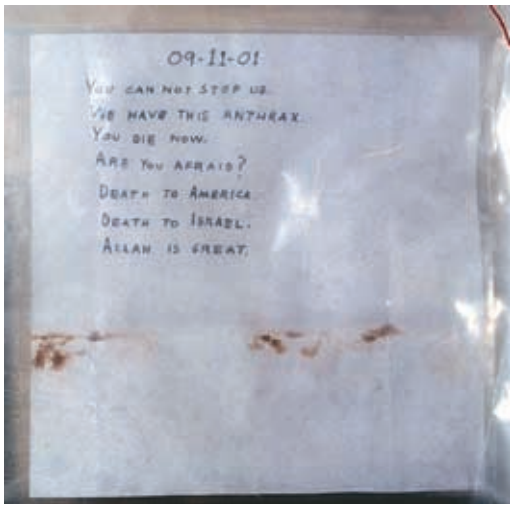

Fig 1. Anthrax Letter

FACTORS INFLUENCING USE OF BA

Scope of the Problem

Biological weapons are unique in their potential ability to inflict large numbers of casualties over a wide area with minimal logistical requirements and by means that can be virtually untraceable. Although wide area delivery of a BA may be technically challenging, the ease and low cost of producing an agent, the difficulty in detecting its presence and protecting (and treating) its intended victims, and the possibility to selectively target humans, animals, or plants conspire to make defence against this class of weapon particularly difficult.

The nations of NATO remain highly vulnerable to the strategic, tactical, and terrorist use of biological weapons. As the military and economic gaps between nations grow and as some less advantaged nations seek a balance of power, there may be a tendency by these nations to overcome their disadvantage by choosing weapons of mass destruction that can be produced easily and cheaply. The purely financial advantage of employing biological weapons

was clearly illustrated by a 1969 expert United Nations panel which estimated the minimum cost of attacking civilian populations at $1/km^2$ for biological weapons, versus $600/km^2$ for chemical, $800/km^2$ for nuclear, and $2,000/km^2$ for conventional armaments.

In contrast to all other weapon systems the full impact of a BW attack may take several days or even weeks to develop, and is difficult to predict during the early stages. A BW attack using an agent transmissible from man-to-man may spread to susceptible personnel and will require control measures such as Restriction of Movement (ROM).

A BW attack will take place against a background of continuing natural disease already present in the operational area or amongst the deployed forces. The initial effects of a biological attack on exposed personnel may be difficult to distinguish from a natural outbreak of disease.

Fig 2. Iraqi Warheads.

Characteristics of BA

Characteristics. Intrinsic features of BA, which influence their potential for use as weapons, include: infectivity; virulence; toxicity (toxins); pathogenicity; incubation period; transmissibility; lethality; and stability. Infectious organisms have to multiply within the body in order to cause disease, in contrast to toxins where the effect is dependent upon the dose received.

Pathogenicity. This reflects the capability of an infectious BA to cause disease in a susceptible host.

Infectivity. The infectivity of a BA reflects the relative ease with which microorganisms establish themselves in a host species. Pathogens with high infectivity cause disease with relatively few organisms, while those with low infectivity require a larger number. High infectivity does not necessarily mean that the symptoms and signs of disease appear more quickly, or that the illness is more severe.

Virulence. The virulence of an agent reflects the relative severity of disease produced by a BA. Different microorganisms and different strains of the same microorganism may cause diseases of different severity.

Toxicity. The toxicity of a BA reflects the relative severity of illness or incapacitation produced by a toxin, and is dose dependent.

Incubation Period. A sufficient number of microorganisms or quantity of toxin must penetrate the body to initiate infection (the infective dose), or intoxication (the intoxicating dose). Infectious agents must then multiply (replicate) to produce disease. Although toxins do not multiply, once in the body they need time to reach target organs before producing their effects. The time between exposure and the appearance of symptoms is known as the incubation period (microorganisms) or latent period (toxins). This is governed by many variables, including the initial dose, virulence, route of entry, rate of replication, and host immunological factors. For any given BA the incubation period is never less than a minimum incubation time.

Transmissibility. Some infectious BA can be transmitted from person-to-person directly. Indirect transmission (for example, via arthropod vectors such as body lice) may be a significant means of spread as well. In the context of BW defensive operations the relative ease with which an agent is passed from person-to-person (that is, its transmissibility) constitutes a primary concern.

Lethality. Lethality reflects the relative ease with which an agent causes death in a susceptible host. Lethality is expressed as the number of deaths in relation to the number of casualties. This is synonymous with case fatality rate.

Stability. The viability of an agent is affected by various environmental factors, including temperature, relative humidity, atmospheric pollution, and sunlight. A quantitative measure of stability is an agent's decay rate (for example, "aerosol decay rate").

Infectious Dose. The dose of an organism needed to infect a person varies widely between individuals and is therefore usually given as the median infectious dose – the dose needed to infect 50% of those exposed. The dose required to infect all the population may be 100 or 1000 times greater than this in some cases, whilst a few percent of the population may be infected by much smaller doses. In practical terms therefore, even a relatively low dose from a small release of BA will cause some casualties in a population of troops. These cases may be patchy in distribution,

especially as the dissemination of the BA will not be evenly distributed with local highs and lows in the concentration of BA. The effect of medical countermeasures is to increase the median infectious dose for the population.

Lethal Dose. The dose of a BA needed to cause death in a given population of individuals (usually related to toxins).

Additional Factors. Additional factors that may influence the suitability of a BA as a biological weapon include ease of production, stability when stored or transported, and ease of dissemination.

Classification.

Medical. Classification of BA is important to the medical services in terms of identification, prophylaxis, and treatment. BA may be genetically modified in order to evade standard detection, identification and medical countermeasures. BA that may be used as weapons can be classified as follows:

- *Bacteria.* Bacteria are small free-living organisms, most of which may be grown on solid or liquid culture media. The organisms have a structure consisting of nuclear material, cytoplasm, and cell membrane. They reproduce by simple division. Some bacteria such as rickettsiae and chlamydia can only grow inside host cells and therefore cannot be grown readily on artificial media. Other bacteria, for example that causing anthrax, can form spores that enable them to survive for long periods in the environment. Diseases produced by bacteria often respond to specific therapy with antibacterial drugs such as antibiotics.
- *Viruses.* Viruses are organisms that require living cells in which to replicate. They are therefore intimately dependent upon the cells of the host, which they infect. They produce diseases which do not respond to antibiotics but which may be responsive to antiviral compounds, of which there are few available, and those that are available are of limited use.

Fig 3. Line source dispersal.

- *Fungi.* Fungi are simple organisms widespread in nature. Most fungi form spores, and free-living forms are found in soil. Fungal diseases may respond to various antifungal drugs. Although some fungi are capable of causing disease in humans they are unlikely to be used as a BW agent. Fungi are not considered further in this document.
- *Toxins.* Toxins are poisonous substances produced and derived from living organisms. Toxins may be countered by specific antisera, only a limited range of which are available.

Operational. The primary characteristics of potential BA are listed in Medical Classification of Potential Agent 1, 2 & 3 in order to provide guidance to field commanders on their impact on operations. Operational considerations should incorporate all recognised variables likely to impact on effectiveness, to include lethality, transmissibility, and persistence.

Dissemination.

Dissemination is the process by which BA are dispersed to cause disease or intoxication. BA are most likely to be delivered covertly and by aerosol. The same routes of entry pertinent to natural spread of diseases (that is, through inhalation, ingestion, or percutaneous inoculation) are also relevant when their aetiological agents are delivered intentionally by weapons. Other routes of entry are thought to be less important than inhalation but are nonetheless potentially significant.

Aerosol. BA can be delivered effectively by a wide range of platforms. The agent can be formulated as either a liquid or dry powder fill. The dissemination can be performed using simple or sophisticated spray devices, by an explosive charge, or simply packaged and delivered in the regular mail. Most forms of aerial delivery including bombs, shells, missiles and aircraft (usually low flying) sprays can be deployed, however spray devices can be effective from ground level. Depending on the efficiency of the delivery system used, some agent may be destroyed at the time of release, larger particles will fall to the ground producing local contamination and respirable particles generated will present predominantly as an inhalation hazard travelling distances downwind.

Contamination of Food and Water. Direct contamination of consumables, such as drinking water or foodstuffs, could be used as a means to disseminate infectious agents or toxins. Some foodstuffs, for example chocolate, can allow organisms to survive for long periods, and significantly reduce the number of organisms required to cause

Fig 4. Ground based aerosol generation.

disease. This method of attack would be most suitable for sabotage activities and might be used against limited targets such as water supplies or food supplies of a military unit or base. Water purification systems significantly reduce this hazard, but supplies may be contaminated following treatment.

Fig 5. Novel dissemination techniques.

Other Considerations

Attempts might be made to spread typical vector-borne diseases by releasing infected natural (or unnatural) arthropod hosts such as mosquitoes, ticks or fleas. These live vectors can be produced in large number and infected by allowing them to feed on infected animals, infected blood reservoirs, or artificially-produced sources of a BA.

Long-term survival of infectious agents, preservation of toxin activity during extended periods, and the protective influence of dust particles onto which microorganisms adsorb when spread by aerosols have all been documented. The potential exists, therefore, for the re-suspension of infectious particles from previously contaminated surfaces. To a lesser extent, particles may adhere to an individual or to clothing creating additional but less significant exposure hazards.

Humans, as unaware and highly effective carriers of a transmissible agent, could readily become a source of dissemination (for example, with plague or smallpox). Consideration should be given to movements of non-military populations including Displaced Persons and Refugees (DPRE).

Routes of Entry

Respiratory Exposure *(Inhalation)*

The natural process of breathing causes a continuing influx of BA to exposed individuals resulting in a cumulative exposure. The major risk is pulmonary retention of inhaled particles in the alveoli where they are maximally effective. Droplets as large as 20 microns can infect the upper respiratory tract; however, these relatively large particles generally are filtered by anatomic and physiological processes, and only much smaller particles (ranging from 0.5-5 microns) reach the alveoli efficiently. Still smaller droplets are inhaled, but they are not efficiently retained in humans.

Fig 6. Contamination of food.

Aerosol delivery systems aim to generate invisible clouds with particles or droplets between 0.5 and 10 microns in diameter, which can remain suspended for long periods. Infection by the respiratory route may induce disease at doses lower than those generally associated with naturally acquired infections by the oral route. The subsequent illness may differ from the natural pattern, and the incubation period may be shorter.

Alimentary Exposure *(Ingestion)*

Food and water supplies may be contaminated during a BW attack either directly or coincidentally. Unwary consumption of such contaminated materials could result in disease.

Dermal Exposure *(Percutaneous)*

Intact skin provides an excellent barrier for most BA. However, mucous membranes, the conjunctiva and damaged skin constitute breaches in this normal barrier through which BA may readily pass, causing local or systemic infection. BA can be introduced through the skin via vectors.

Levels of Hazard

The possible levels of challenge to personnel subjected to a BW attack in any operational environment will vary significantly in place and over time, depending on the nature of the delivery system employed.

On-Target-Attack: where the point of release of the BA occurs within the target location. These attacks are much less likely to be covert, enabling personnel to assume defensive measures in a more timely manner (respiratory protection and post exposure prophylaxis):

- *Primary Aerosol.* Large concentrations of aerosolised agent may be generated very quickly by an On-Target-Attack, whether from spraying or bursting munitions, exposing personnel to high levels of inhaled challenge. Protection against such challenge levels may require the combined employment of medical prophylaxis and full respiratory protection (individual or collective) for as long as the primary aerosol persists in location, until dispersed, diluted or possibly decayed, which may

take several hours, particularly in atmospherically stable conditions. There will be a significant down wind hazard for many kilometres, the exact area depending on wind speed, direction, and size of release. Significant differences in the effect of weapons are seen with different atmospheric conditions including humidity, ultraviolet light (sunlight), temperature and time of day. In addition, pockets of aerosolised BA may persist for longer periods of time within confined spaces: buildings, shelters and vehicles, even after the primary aerosol has dispersed or moved on.

- *Residual Contamination.* While data on the significance of residual contamination following a BA aerosol attack is incomplete, it is anticipated that any on target delivery system will produce a degree of surface contamination close to the point of release. Relative to the primary aerosol, the immediate hazard associated with contam-ination will be considerably less than that of the primary aerosol, unless there is a risk of percutaneous exposure, for example through wounds sustained during the attack. The persistence of residual contam-ination is uncertain, but will be substantially longer than the BA in aerosol form. Once the primary aerosol has moved from the location residual contamination will represent a continued decreasing hazard, for several hours to days, either from localised re-suspension, cross-contamination, ingestion or percutaneous inoculation. Even relatively low levels of residual contamination may be viewed as significant if personnel remain contaminated or are required to continue operating in the contaminated area. Protection against inhaled and percutaneous hazards may be afforded by the use of medical prophylaxis, the continuous use of appropriate physical protection (with associated operational degradation) and high standards of personal and unit hygiene.

- *Re-aerosolisation.* Residual contamination may be re-aerosolised by the movement of both vehicles and personnel. At this time the operational impact of re-aerosolised BA cannot be measured, therefore, a worse-case scenario should be assumed.

Off-Target-Attack: where the point of release of the agent occurs outside the target location. BA used in such an attack must be sufficiently stable to reach the target location in a viable form. Off-Target-Attacks are more likely to be covert, denying exposed personnel the opportunity to take timely defensive measures. A similar state will exist downwind of an On-Target-Attack:
- *Primary aerosol.* The behaviour of aerosolised BA entering a location after release off-target will be the same as for an On-Target-Attack, although at a generally reduced level of concentration for the same amount of BA released. Furthermore, dispersion of the aerosol cloud prior to arrival may result in large variations of concentration within specific areas of the location.

- *Residual contamination.* Off-Target-Attacks are very unlikely to produce any significant contamination hazard as a result of the deposition of aerosolised BA onto surfaces, other than the potential to contaminate unprotected supplies of food and water, in which deposited BA may multiply or survive for long periods of time.

- *Re-aerosolisation.* Off-Target Attacks have a lower likelihood of producing significant re-aerosolisation of BA compared to On-Target Attacks due to lower levels of residual contamination. However, consideration should be given to the possibility of re-aerosolisation where an Off-Target Attack is detected sufficiently early to take defensive action.

- *Incubation Phase.* Following exposure to a BA there will be a time delay before symptomatic cases of disease occur consistent with the incubation period of the microorganism (or latent period of the toxin) and the dose received by the individual. This will be days to weeks after the initial attack, long after the hazard from the primary aerosol has passed. The numbers of casualties in any exposed population may be difficult to predict. Primary cases may occur over several days amongst those in the hazard area from the original attack. If the disease spreads directly from person to person, personnel in close contact with the initial cases may become infected. This secondary spread may be controlled by medical prophylaxis and strict infection control measures including Restriction of Movement (ROM) as described in the relevant chapter. BA with zoonotic potential may lead to spread of disease between animals and humans and would require institution of measures to control human contact with animal populations.

- *Latency Phase.* Following exposure to toxins there will be a time delay of hours to days before symptoms of intoxication may occur. This time period is dependent on the agent, the dose and the exposure route.

- *Animal Surveillance.* Many BW agents also cause disease in animal populations, therefore, the onset of signs and symptoms in man will coincide with illness or death within animal populations.