Calculations of the Potential Impact of BW and BT

Lecture No. 5

Notes: The aim of this lecture is to give students a firm basis for understanding the dangers involved if there is a resurgence of offensive biological weapon programmes by discussing some of the numerical data available in the open literature.

1. Overview

- Military Characteristics of BW Agents
  - Slides 2 - 5
- WMD/Strategic BW Attacks
  - Slides 6 - 12
- Production of BW Agents
  - Slides 13 - 16
- Other Types of BW Attack
  - Slides 17 - 20

Notes: Much of this lecture draws on chapters of Dando, M.R. (1994) *Biological Warfare in the 21st Century: Biotechnology and the Proliferation of Biological Weapons*. Brassey's, London. However, references are given to the original literature used.

Ref:

Dando, M.R. (1994) Biological Warfare in the 21st Century: Biotechnology and the Proliferation of Biological Weapons. Brassey's, London

2. Military Characteristics (i)

- The diversity of potential BW attacks
  - Different targets (humans, animal and plants)
  - Different agents (bacteria, viruses, fungi, toxins, bioregulators)
  - Different scales (assassination, tactical military, strategic military, WMD)
  - Different purposes (overt or covert war or terror)

Notes: It is important to stress at the outset that although the lecture concentrates on military strategic aspects of BW because of the link to state-level offensive programmes there is a very wide diversity of possible BW attacks.

3. Military Characteristics (ii)

- A military classification of BW agents
  - Potentially infectious from first victim
    - Incapacitating (e.g influenza virus)
    - Lethal (e.g. *Yersinia pestis* - plague)
  - Not infectious from first victim
    - Incapacitating (e.g. *Coxiella burnetii* - Q-fever)
    - Lethal (e.g. *Bacillus anthracis* - anthrax)

Notes: Clearly it would be possible to greatly degrade the efficiency of a military force if an effective incapacitating agent was used in an attack and in fact such agents were weaponised in the last century's offensive programmes. Most attention is naturally given to lethal agents, but this is to misunderstand the range of possibilities. Again it is often believed that only non-infectious agents were weaponised, but plague, for example, was weaponised by the former Soviet Union.

4. Military Characteristics (iii)

- Militarily-desirable characteristics of BW agents
  - An agent should produce a certain effect consistently
  - The dose needed to produce the effect should be low
  - There should be a short and predictable incubation period
  - The target population should have little or no immunity

Notes: This and the following slide set the context for the later discussion of the doses needed for BW attacks on people.

5. Military Characteristic (iv)

- Militarily-desirable characteristic of BW agents (cont.)
  - Treatment for the disease should not be available to the target population
  - The user should have means to protect troops and civilians
  - It should be possible to mass produce the agent
  - It should be possible to disseminate the agent efficiently
  - The agent should be stable in storage and transport in munitions.

6. WMD/Strategic Attacks (i)

- United Nations Study in 1969
  - Single bomber using 10tons of BW agent
    - Area affected 100,000 km^2
    - Morbidity 50%, 25% deaths if no treatment
  - Area affected if a 1 megaton nuclear bomb was used
    - 300 km^2
  - Area affected if 15 tons of nerve agent was used
    - 60 km^2

Notes: In the lead up to the negotiation of the BTWC the United Nations Secretary General published a report on *Chemical and Bacteriological (Biological) Weapons and the Effects of their Possible Use*. This example is taken from the report. It makes clear that in the right conditions biological weapons could be even more dangerous than nuclear weapons in causing illness and death. It should be stressed that the international experts, who were the consultants for the report, were people who knew what they were dealing with. An example is Sir Solly Zuckerman, Chief Scientific Adviser to the UK Government.

7. WMD/Strategic Attacks (ii)

- SIPRI 1973 Study
  - Single bomber with 5-6 ton bombload
  - Area in km^2 over which 50% casualties would be possible
    - High explosive 0.22
    - VX nerve gas 0.75
    - 10kt nuclear bomb 30
    - Biological agent 0 -50 (depending on weather conditions)

Notes: In the early 1970s the Stockholm International Peace Research Institute (SIPRI) published its classic series of books on *The Problem of Chemical and Biological Warfare*. This example is taken from volume II *CB Weapons Today*. The huge potential impact of the use of a BW agent is again very clear in comparison to other possible weapons

Ref:

SIPRI (1973) *The Problem of Chemical and Biological Warfare: CB Weapons Today*. Vol. II. Stockholm: Almqvist & Wiksell.

8. WMD/Strategic Attacks (iii)

- Fetter's 1991 study in the journal *International Security*
  - Missile with throw weight of one tonne attacking a large city with 30 people per hectare density
    - 20kt nuclear weapon would kill 40,000
    - 300kg Sarin would kill 200 - 3,000
    - 30kg anthrax would kill 20,000 - 80,000

Notes: Fetter's study Ballistic missiles and weapons of mass destruction: What is the threat? What should be done? *International Security* **16**, (1) 5-42 was published as the Cold War was coming to an end. Thus 20 years had passed since the UN and SIPRI studies, but the view of the comparative danger of BW as against other weapons had not changed.

Ref:

Fetter, S. (1991). 'Ballistic Missiles and Weapons of Mass Destruction: What is the Threat? What should be Done?', *International Security* **16**(1): 5-42. Available from http://www.mitpressjournals.org/is

9. WMD/Strategic Attacks (iv)

- US Office of Technology Assessment 1993 report: Scenario I
  - Attack with a missile delivered on an overcast day or night, with a moderate wind on a city with 3,000 to 10,000 unprotected people per km^2
    - 12.5 kt nuclear weapon would destroy 7.8km^2 and kill 23,000-80,000 people
    - 300kg of Sarin would kill 60-200 people in an area of 0.22km^2
    - 30kg of anthrax would kill between 30,000 to 100,000 in cigar shaped plume from the warhead covering 10km^2

Notes: The Office of Technology Assessment was a highly regarded institution and its reports were considered authoritative around the world. This report on *Proliferation of Weapons of Mass Destruction :Assessing the Risks,* OTA-ISC-559 of August 1993 has been quoted by many subsequent authors. The comparative effects of the different types of weapon remain as in other studies reviewed here.

Ref:

U.S. Congress, Office of Technology Assessment. (1993). *Proliferation of Weapons of Mass Destruction: Assessing the Risks* (Document No. OTA-ISC-559). Washington, DC: U.S. Government Printing Office. At p. 53

10. WMD/Strategic Attacks (v)

- US Office of Technology Assessment 1993 report: Scenario II
  - Attack by a plane releasing 10kg of anthrax along a line on the windward side of a city like Washington DC
    - On a clear sunny day with a light breeze, 46km^2 would be affected and 130,000 to 460,000 people could die

Ref:

U.S. Congress, Office of Technology Assessment. (1993). *Proliferation of Weapons of Mass Destruction: Assessing the Risks* (Document No. OTA-ISC-559). Washington, DC: U.S. Government Printing Office. At p. 54.

11. WMD/Strategic Attacks (vi)

- OTA Scenario II (cont)
  - On an overcast day or night with a moderate wind, 140km^2 would be affected and 420,000 to 1,400,000 people could die
  - On a clear, calm night an area of 300km^2 would be affected and between 1 and 3 million people could die
  - Clearly the use of such a line source of such an agent in ‘ideal’ conditions (e.g. in the absence of UV light that would kill the spores more rapidly) could be devastating as it would be difficult to assist so many people

Notes: Such scenarios developed by well-informed analysts have to be taken seriously. While anthrax is treatable if antibiotics are started early enough it is hard to see how any public health system could cope with disease on this scale.

Ref:

U.S. Congress, Office of Technology Assessment. (1993). *Proliferation of Weapons of Mass Destruction: Assessing the Risks* (Document No. OTA-ISC-559). Washington, DC: U.S. Government Printing Office. At p. 54.

12. WMD/Strategic Attacks (vii)

- Some munitions known from the US BW programme
  - Warhead for guided missile M210 with bomblets (M143) in the warhead under development in 1967
  - Spray tank for liquid agent A/B45Y-1 used by high speed tactical aircraft under development in 1965

Notes: The authors of the SIPRI volume II gave a list of a wide variety of munitions under development in the US programme and there were clearly increases in the efficiency of the munitions as the research and development effort continued over two and a half decades. Indeed, BW attacks were increasingly subject to careful calculation as the last century progressed. As we shall see in the following slides, calculations can be made of the dose required to be delivered to infect 50% of the people in a particular area if certain parameters are known.

13. Production of BW Agents (i)

- Growth of a bacterial agent by fermentation requires
  - A seed culture of the virulent pathogen
  - Initial propagation in small fermenters
  - Growth in production-scale fermenter
  - Collection of the agent from the fermenter
  - Final processing such as freeze drying

Notes: In 1993 the Office of Technology Assessment also produced a background report on *Technologies Underlying Weapons of Mass Destruction* (Document No. OTA-BP-ISC-115), December. This outlines the means by which bacterial and other agents could then be produced. This listing is taken from the report. It should not, however, be assumed that the production of an effective agent would be straightforward. Leaving aside the difficulties of obtaining a virulent strain and difficulties in final processing, bacterial fermentation can be damaged by contamination and genetic mutation that lead to loss of agent potency.

Ref:

Office of Technology Assessment. (1993). *Technologies underlying Weapons of Mass Destruction* (Document No. OTA-BP-ISC-115). Washington, DC: U.S. Government Printing Office. At p. 87

14 Production of BW Agents (ii)

- Estimation of the quantity of agent needed for a line attack
  - Consider first a point source from which the dose (**D**) received by a victim is
    - **Q** the source strength (units/m) times **b** the breathing rate (volume/minute) divided by **h** the depth of the air layer times ū the mean surface wind speed
    - Thus

$$D = \frac{Q.b}{h.\bar{u}}$$

This simple model was used by a UK official in a NATO Advanced Research Workshop in 1996 to estimate the amount of agent required and thus the size of production needed in a discussion of the possibility of detecting such production.

Ref:

Annex A produced in Bartlett, T. B. (1996) *The Arms Control Challenge: Science and Technology Dimension*, Paper presented at the NATO Advanced Research Workshop, The Technology of Biological Arms Control and Disarmament Budapest, 28-30 March.

15. Production of BW Agents (iii)

- Consideration of a point source (cont)
  - The source strength required is clearly
    - $Q = \frac{D.h.\bar{u}}{b}$
  - Using typical values for these quantities
    - **b**=20 litres/min (2.10^{-2} m^3min^{-1}); **h**=1km (10^3m); $\bar{u}$= 5m/s (3.10^2mmin^{-1})
  - Thus if D is 10 times the Infective Dose (ID_{50})
    - $Q = \frac{10.ID_{50}.10^3.3.10^2}{2.10^{-2}} = 1.5.10^8.ID_{50}$
  - So the attacker needs about $10^8 ID_{50}$/m

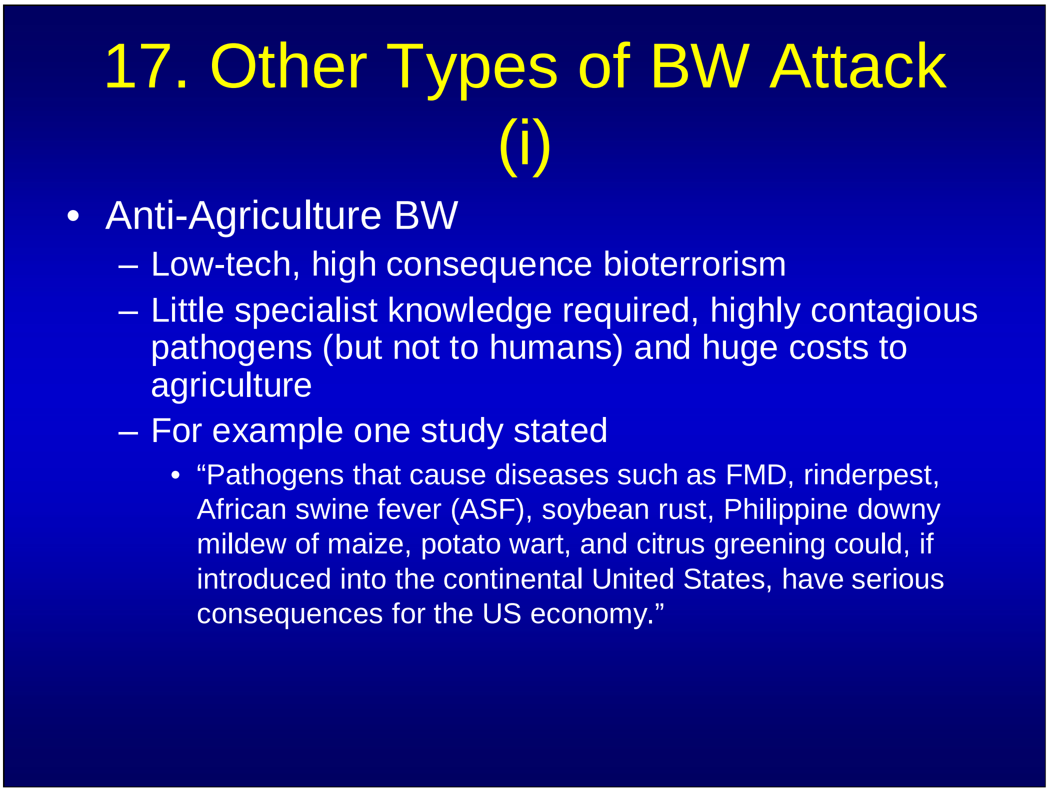
16. Production of BW Agents (iv)

- For a line source 10km long attacker needs
  - 10^8 ID_{50} times 10^4 $=10^{12} ID_{50}$
- Assume a concentration of 10^8 bacterial cells per ml is possible in the fermenter so the attacker will need to produce
  - 10^{12} times (No. of cells equivalent to 1 ID_{50})/10^8times1000) liters of suspension
- Given the ID_{50} for anthrax is about 10^4 the attacker would need about 100,000 liters which would be possible in ten runs of ten fermenters of 100 liters capacity

Notes: This illustrative calculation for a box model shows that making reasonable assumptions the attacker needs 10^{12} ID_{50} to be released into the atmosphere. This is called the 'trillion dose criterion' and similar values are said to come from the consideration of other scenario models.

Ref:

Annex A produced in Bartlett, T. B. (1996) *The Arms Control Challenge: Science and Technology Dimension*, Paper presented at the NATO Advanced Research Workshop, The Technology of Biological Arms Control and Disarmament Budapest, 28-30 March.



Notes: This form of attack should be given special attention because it is often not realized that it is perhaps the most likely devastating form of terrorism we are likely to see in the near future.. The quote is taken from Wheelis, M.L., Madden, L.V. and Cassagrande, R. (2002) Biological attacks on agriculture:low tech, high impact bioterrorism. *Bio-Science*, **52**, 569-76. at p. 570

18. Other Types of Attack (ii)

- Terrorist attacks on people
  - US Congressional Research Service 2004 report cautions against drawing direct analogies from consideration of State programmes
    - “C/B agents that were considered high threats in other frameworks appear to present a lesser threat when viewed in the small scale attack context. Conversely, C/B agents that were considered of lesser threat when considering mass casualty attacks may be ranked more highly in the small scale context, as barriers to mass use may be missing when the agent is used on a small scale.”

Notes: The Congressional Research Service report by Shea, D.A. and Grotton, F. was titled *Small-Scale Terrorist Attacks Using Chemical and Biological Agents: An Assessment Framework and Preliminary Comparisons.* It is discussed in Chapter 7 of Dando, M.R.(2006) *Bioterror and Biowarfare*, Oneworld Publications, Oxford. The point that needs to be made is that when considering possible smaller scale attacks it is very important to rethink what would be easy for the terrorist to do. As the next two slides show, even in attacking people there may be great differences from the barriers that need to be overcome in relation to state programmes.

19. Other Types of Attack (iii)

- World Health Organisation 1970 report considered a range of possible WMD and other scenarios
  - A lethal and incapacitating antibiotic-resistant biological weapon without secondary cases (tularaemia)
  - A lethal and incapacitating antibiotic-sensitive biological weapon with secondary cases (pneumonic plague)
  - Contamination of the water supply with typhoid bacillus or botulinal toxin A

Notes; In the run up to the agreement of the BTWC the World Health Organization published the first (1970) edition of its account of 'Health Aspect of Chemical and Biological Weapons'. In annex 4 this considers 'Medical and Public Health Effects of Attack with Chemical or Biological Weapons'. This annex reviews a range of possible WMD attack scenarios and their consequences. Annex 5, however, considers sabotage of water supplies - a different type and scale of attack.

20. Other Types of Attack (iv)

- 1kg of freeze dried culture of typhoid used to attack the water supply of a city of 1 million in a hot arid developing country. The attack was without warning so no special precautions were taken by the authorities
  - Raw water consumption assumed to be two litres per person per day and so 125,000 people calculated to receive 100,000 microorganisms and many would therefore become ill
  - If no facilities were available for mass treatment some 4,500 people might die because of the attack

Notes: The WHO assumed that the amount of culture would be reduced by 95% because of die off in the mains. The infection rate was calculated from known human data and the death rate without treatment was calculated to be 10%. So it has been clear from such analyses for decades that many other types of effective attack could be carried out with biological agents. Note that typhoid would not figure high on the pathogens of concern in state-level programmes - just as shown in slide 18.

Sample Questions

1. Critically evaluate the military-significant features of: Plague, Influenza, Tularaemia, Botulinum Toxin and Q Fever.

2. What are the structural difficulties that make a large scale antipersonnel biological attack rather unlikely at this time?

3. Discuss some of the calculations in the open literature that suggest that under certain conditions biological weapons could be used as Weapons of Mass Destruction (WMD).

4. Anti-agriculture is the most likely form of very successful bioterrorism today. Discuss.

References

(Slide 1)

Dando, M.R. (1994) Biological Warfare in the 21st Century: Biotechnology and the Proliferation of Biological Weapons. Brassey's, London

(Slide 6)

United Nations (1969) *Chemical and bacteriological (biological) weapons and the effects of their possible use: report of the Secretary-General*. A/7575/Rev.1, S/ 9292/Rev.1, New York, United Nations. Available from http://unbisnet.un.org/

(Slide 7)

Robinson, J. P., Hedén, Carl-Göran., and von Schreeb, H. (1973) *The Problem of Chemical and Biological Warfare: CB Weapons Today*. Vol. II. Stockholm: Almqvist & Wiksell. Available from http://books.sipri.org/index_html?c_category_id=58

(Slide 8)

Fetter, S. (1991). ‘Ballistic Missiles and Weapons of Mass Destruction: What is the Threat? What should be Done?’, *International Security* **16**(1): 5-42. Available from http://www.mitpressjournals.org/is

(Slide 9-11)

U.S. Congress, Office of Technology Assessment. (1993). *Proliferation of Weapons of Mass Destruction: Assessing the Risks* (Document No. OTA-ISC-559). Washington, DC: U.S. Government Printing Office.

(Slide 13)

Office of Technology Assessment. (1993). *Technologies underlying Weapons of Mass Destruction* (Document No. OTA-BP-ISC-115). Washington, DC: U.S. Government Printing Office

(Slide 14 and 16)

Bartlett, T. B. (1996) The Arms Control Challenge: Science and Technology Dimension, Paper presented at the NATO Advanced Research Workshop, The Technology of Biological Arms Control and Disarmament Budapest, 28-30 March.

(Slide 17)

Wheelis, M. Madden, L.V. and Cassagrande, R. (2002) Biological Attacks on Agriculture: Low Tech, High Impact Bioterrorism. *Bio-Science*, 52, 569-76. Available from http://www.accessmylibrary.com/comsite5/bin/aml2006_library_auth_tt.pl?item_id=0286-25690504

(Slide 18)

Shea, D. A., and Gottron, F. (2004) Small-scale Terrorist Attacks Using Chemical and Biological Agents: An Assessment Framework and Preliminary Comparisons, *CRS Report for Congress* [Online] FAS [accessed 27 January 2009] available from http://www.fas.org/irp/crs/RL32391.pdf

(Slide 19)

World Health Organization (1970) *Health Aspects of Chemical and Biological Weapons*, Geneva: WHO. Available from http://www.who.int/csr/delibepidemics/biochem1stenglish/en/index.html