

A Magic Sword or a Big Itch: An Historical Look at the United States Biological Weapons Programme

ALASTAIR HAY

School of Medicine, University of Leeds, Leeds LS2 9JT

In the late 1950s interest in entomological warfare increased, and literature describing the US biological warfare programmes on the use of the mosquito *Aedes aegypti*, the vector for transmitting yellow fever, has now been released. Yellow fever was considered as a suitable disease to use in southern regions of the former Soviet Union. The US destroyed its biological weapon stockpiles in the early 1970s.

In addition to its offensive biological warfare programme, the US conducted extensive trials to assess its own vulnerability to biological attack. These trials and a later series of threat analyses indicate that biological agents could, indeed, affect large areas of the US if the attackers were allowed to proceed unmolested. Some of the threat analyses present highly questionable scenarios.

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Entomological Warfare: Target Analysis

The annual reports of the US Chemical Corps provide some background to the United States interest in using yellow fever as a biological warfare agent.¹ The annual reports, however, only provide a brief summary of the work completed. A far more detailed picture is given by a range of specific reports on yellow fever research efforts. Before yellow fever could be given serious consideration as a biological warfare agent, some background work on the epidemiology of the disease and the ecology of the target area was required.

A report on the likely target area for the use of the yellow fever virus, together with five annexes, provides the background to the United States belief that the disease was a viable biological warfare agent. Part of the research effort on the epidemiological analysis was contracted out to Dr Lewis P. Gebhardt, head of the Department of Bacteriology at the University of Utah. Assistance for Dr Gebhardt was received from the Ecology and Epidemiology branch at Dugway Proving Ground.²

The report notes that the Rockefeller Foundation and other groups had studied the requirements for initiating an epidemic of urban yellow fever. Many research groups have investigated the epidemics caused by yellow fever and there is a vast open literature on the subject. According to entomological warfare target analysis, the requirements for an urban yellow fever epidemic were as follows:

- the presence of vector mosquitoes in over 1% of the houses (generally 3–5%)
- the presence of the yellow fever virus
- presence of susceptible persons
- temperatures from 61°–101° F.

Gebhardt's detailed analysis of the scientific literature is contained in the first annexe of five mentioned.² At the time the report was produced, it was estimated that there were some 75 distinct viruses known or suspected of being arthropod-borne. Many of these viruses belonged to three immunologically related families, referred to as groups A, B and C. Group B is the largest and most important of the three and yellow fever is classified in this group. The report notes that the group B 'arthropod-borne' viruses have been further classified into related sub-groups.

The analysis deals mainly with a group of eighteen arthropod-borne viruses belonging to the arbor group B. These viruses were noted to have the ability to multiply in an arthropod vector without manifestation of disease, transmitting it to susceptible subjects which become virus hosts 'from which another arthropod vector may obtain the virus-containing blood meal and thus continue the cycle'.² Gebhardt thoroughly reviews the epidemiology of the viruses and the epidemics recorded in the literature. Host susceptibility and resistance are also considered, along with the immunity of individuals.

The mosquito most favoured for the transmission of yellow fever virus was *Aedes aegypti*. However, this mosquito is also a vector for a related infection, dengue fever. This factor raised a number of questions about the efficacy of the vector where yellow fever was concerned. The open literature demonstrated conclusively that yellow fever and dengue fever occurred in the same areas both endemically and epidemically. The possibility was considered that individuals infected with dengue fever who had gone on to develop an immunity to it might also have resistance to yellow fever. Gebhardt's analysis ruled out such a situation. His review of the literature led him to conclude that it was 'apparent that at best, dengue fever immunity would have little effect on the susceptibility to yellow fever virus, provided at least two months elapsed after dengue fever convalescence before exposure to yellow fever virus'. He also concluded from the literature reports that if *Aedes aegypti* was infected with yellow fever virus, then 'dengue virus would not multiply in this mosquito'. His analysis of the available literature remains classified as secret and sections

of his report were excised and remain outside the public domain. The fourth annexe of the Entomological Warfare Target Analysis document is a detailed review of ten species of mosquito known to be potential vectors of yellow fever virus in certain parts of the world. The annexe considers the geographical distribution of the mosquitoes, their seasonal abundance, preferred environment, feeding habits, life cycle, peak biting activity, flight range and vector potential.

The third annexe of the document is a detailed review of the meteorological conditions affecting Eurasia. Referring to a range of data sources the report maps the rainfall, fog, likely surface conditions and cloud cover at different times of year over Europe and Asia. Sections of this annexe have been excised from the report made available under the FOI Act. However, with judicious reading, and by peeling back certain cut pages it is possible to identify a number of specific cities for which more details were provided. These were Stalingrad, Moscow, Vladivostock, Tsingtao, Shanghai, Basra, Cairo and Canton. Annexes four and five to the document are secret and the majority of the pages have been excised from the papers made available. Annexe four details the defensive capability of the presumed target areas. The only section which has not been excised provides information relating to the departments of the ministry of health of the USSR, and the medical facilities and public health administration in the former Soviet Union.

Annexe five, which considers target analyses, provides no information at all. The complete content of the annexe has been excised and is not in the public domain.

The main report provides a number of scenarios, which consider the situation in a likely target area following the release of *Aedes aegypti* mosquitoes infected with yellow fever where 99% of the vector population are female mosquitoes. Females of this species were the preferred vectors for yellow fever, and they are fertilized very quickly after their wings dry. According to Gebhardt (in Annexe One),² after fertilization the females seek a blood meal. After her eggs are laid, between 15 and 36 hours elapse before the larvae hatch out. If the female takes a blood meal from the host within the first three days of fever caused by yellow fever infection, the mosquito may become a carrier of the virus for the rest of its natural life. A mosquito can survive for between 60 and 76 days, or even longer. The mosquito is incapable of transmitting infection to humans or animals until the virus has multiplied in the insect's salivary glands.

The incubation period of the virus in the salivary glands of the mosquito depends on the ambient temperature. At a temperature of 20°C the maximum viral titre may be reached after 21 days. At 37°C a full viral titre is present after only four days.

The main report of the Entomological Warfare Target Analysis considers various schemes for the possible progress of infection. After being bitten by infected mosquitoes, diseased individuals could in turn be bitten

by uninfected mosquitoes. These insects then become hosts to the virus, initiating a further cycle of infection by transmitting the virus when drawing blood meals from humans. Saliva from the mosquito is injected into the host before withdrawal of blood takes place.

In his review, Gebhardt notes that all nationalities are equally susceptible to the yellow fever virus. Where the disease was endemic, and with particular reference to jungle yellow fever, the immunity level of the native population was fairly high and in these circumstances epidemics were uncommon. Most of this immunity, Gebhardt noted, was due to previous exposure to the virus. In his review, he concluded that 'the general consensus of opinion of all students and historians of yellow fever is that the introduction of foreigners, irrespective of race or nationality, into epidemic or endemic areas of this disease, invariably results in their becoming infected if they have not been immunised, either naturally or artificially'. With this background, the report notes that 'mass vaccinations within the target area have not occurred'. Taking the foregoing information into account, it appears that the analysis of conditions in the Soviet Union suggested that at least part of it would be susceptible to attack using mosquito vectors of yellow fever.

The following phases in the yellow fever programme determined the optimum conditions for the release of mosquitoes. These investigations are detailed in the series of reports relating to Project Bellwether.³⁻⁶

Bellwether One describes the result of the biting activity of starved 'virgin female *Aedes aegypti* mosquitoes upon troops in the open'.³ Fifty-two field trials were conducted between 1 September and 9 October 1959. The basic trial design involved three circles, each with a radius of 15 feet, and located half a mile apart, on a crosswind line. Ten men were placed equidistantly around the perimeter of one circle and traps with guinea pigs were placed around the perimeters of other circles. The volunteers remained seated and 100 insect vectors were released in the centre of each of the circles. The study concluded that wind speed was the most important factor affecting biting activity. It was demonstrated that an increase of one mile per hour in the ambient wind speed reduced biting activity. Many of the results were erratic and it was clear that, in addition to wind speed, temperature, relative humidity and solar radiation all affected the biting activity of the mosquito, and would have to be taken into consideration in any model designed to predict biting activity. The overall outdoor biting activity for the mosquito was estimated to be some 40 bites per hundred mosquitoes in the time period studied.³

Bellwether Two was a more ambitious project, which set out to assess the results of varying the distance between the host and the mosquito. Also considered were the effects of the movement of human subjects on biting activities of the mosquito; and the length of time of the insects' survival in ambient desert conditions. Bellwether Two was conducted in six phases which incorporated an orientation trial, fourteen field trials, and two

laboratory scale trials which took place between August and late October 1960. The outcome of the study suggested that there was no significant difference on biting activity at distances of up to one hundred feet of the release point of the mosquitoes, but that maximum biting activity occurred at distances of less than 200 feet. Increasing the number of mosquitoes caused a proportionate increase in the number of bites. The insects were reported to be more likely to bite human subjects where individuals were alternately moving and then remained motionless. Biting activity was lowest when the human volunteers were continually moving. Individuals near buildings were bitten more often than those in open areas. No conclusions could be drawn concerning the average lifespan of the mosquitoes in desert conditions.⁴

No reference was noted to any project entitled 'Bellwether Three'. Bellwether Four assessed the biting activity of two strains of *Aedes aegypti* mosquito. These were the CD (Camp Detrick) strain and the R (Rockefeller) strain. The biting activity of the mosquitoes was assessed in a built-up area and penetration into buildings was evaluated. Several deficiencies in the study design were noted. Volunteers were given the option to try and kill the mosquitoes or let them be. This created some difficulties in the analyses, due to the fact that it was not clear whether the number of bites recorded involved different mosquitoes, or repeat bites from the same insects. In its conclusion, therefore, the report could find no difference between CD and R strain mosquitoes. There was insufficient information to enable a conclusion to be drawn about the relative biting propensities or the building penetration characteristics of the separate strains. In view of the other inconclusive outcomes of investigations of Bellwether Four, further studies were proposed.⁵⁻⁶

One of the series of 'threat analyses' assessing the vulnerability of the US and European NATO nations to biological warfare attacks discusses entomological warfare. The report reviews the history of related field testing in the US. In addition to brief descriptions of the Bellwether procedures it considers several others including Operations Big Itch, Big Buzz and Drop-Kick, Grid Iron and May Day.⁷ Details concerning Operation Drop-Kick and Grid Iron are not yet in the public domain. Big Itch was a series of trials in 1954 investigating the E-14 munitions for suitability for the dispersal of the flea *Xenopsylla cheopis* from altitudes of 305 and 610 metres over the US Army Dugway Proving Ground. A second munition, the E-23, was also assessed in the study. E-23 was approximately 9¾ inches in diameter and 18 inches long. It was equipped with an external actuating mechanism to release carbon dioxide. This in turn burst a plastic bag inserted in the cylinder, thereby ejecting the fleas. The cardboard cylinder of the E-14 was approximately 13 inches in diameter and 9¾ inches long. The piston ejection mechanism it used relied on an internal carbon dioxide actuating device.⁸

Operation Big Itch led to the conclusion that fleas could be successfully

transferred, reared to an appropriate stage of development, and delivered to a target with few if any of the fleas dying in the process. The fall itself did not affect the insects and after their release they were shown to be able to acquire hosts, in this case, a number of guinea pigs released at regular intervals in the sampling areas. The insects were observed to be active for a period of less than 24 hours following the drop, unless they found a guinea pig host. During the trial eight of the E-23 components malfunctioned. Before the arming process and the dropping of the munitions it was reported that numerous fleas had escaped from the munitions carrier when sealing tape was removed, and insects entered the plane. Thus 'numerous fleas bit the pilot, the bombardier and observer'.⁸

Operation Big Buzz⁷ was a field test conducted in Georgia to demonstrate the feasibility of mass producing, storing and loading mosquitoes into munitions and subsequently disseminating these from aircraft. Approximately one million uninfected *Aedes aegypti* mosquitoes were produced and stored for two weeks. About a third of these were placed in E-14 munitions, were released at a height of approximately 90 metres, and subsequently dispersed by the wind and by their own flight. They were collected from as far as 610 metres downwind from the target release site. The 'female mosquitoes were active in seeking blood meals from humans and guinea pigs'. This research effort on the *Aedes aegypti* yellow fever vector in the US biological weapons programme seems to have been of more value than its use as an offensive weapon alone. According to the evaluation of the threat to the US, the yellow fever virus and vector was 'estimated to be the most likely antipersonnel BW [entomological warfare] system that could be used by the Warsaw Pact countries against the United States or the European NATO nations'.⁷ It appears that the United States military envisaged that biological weapons could be used not only against the Soviet Union, but against other countries as well. The contents page only is available for a report on other targets. The employment of biological weapons against both the 'Soviet homeland' and 'communist China homeland' are mentioned.⁹

Operation Magic Sword¹⁰ appears to be a continuation of the Bellwether series of operations. In Operation Magic Sword, the objective was to assess the biting habits of the *Aedes aegypti* mosquito in a warm humid environment. Mosquitoes were released offshore at distances of 1.6 km and 5.8 km. All the mosquito releases were made shortly after dawn and the insects were recovered at intervals of three, twelve and 24 hours following release. As might be expected, wind had a significant effect on the likelihood of mosquitoes finding a host. There was an 'inverse linear relationship between the percentage of bites obtained (relative to the number of mosquitoes released) and the observed wind speeds'. The Magic Sword report analyses some of the Bellwether data and notes that at a wind speed of 0.6 metres per second, for example, 25.8% of bites were recorded. The percentage figure represents the percentage of bites received relative to

one thousand mosquitoes released. However, at a wind speed of 2.4 metres per second, a figure of only 4.3% of bites was recorded. The Magic Sword study demonstrated that mosquitoes could be reared with a mean 50% of survival of 52 days where batches were kept at a temperature of some 18°C and 80% relative humidity. Following the analysis of the data from Magic Sword, the conclusions concerning the additional data required were that more information was needed about other environments such as tropical jungles, temperate forests and plains. Also required was information on the effects which could be obtained on the number of mosquitoes reaching hosts following modification of the release height, and results on the travelling distance on the insects after release in total darkness, avoiding the effects of heat or solar radiation. It was also considered necessary to discover how well the mosquitoes would fly 'laterally from the transport wind direction to reach a target site'.¹⁰

Biological Field Testing and BW Agent Tests on Volunteers

In 1977 a comprehensive summary of the US Army activities on the biological warfare programme was published. The report details the history of the following:

- the biological weapons programme
- contracts entered into by Fort Detrick with major contractors
- field tests conducted with biological agents and simulants
- the extensive sequence of tests on human volunteers to assess the infectivity of particular biological warfare agents.
- programmes to develop vaccines against these agents.¹¹

Man is the ultimate target for biological warfare, and simulants had demonstrated the vulnerability of the United States to a biological attack. However, no scientific data was available to assess just how vulnerable humans would be to various disease organisms. This gap in the information led to a series of investigations, using human volunteers. Operation 'Whitecoat' was the code name given to the plan to use human volunteers in experiments to assess the pathogenicity of organisms. The protocol for the tests required voluntary informed consent; no experimentation which could predictably lead to death or permanent instability; proper medical supervision and treatment; experiments which would yield fruitful results; and avoidance of any unnecessary physical and mental suffering. Most of the initial volunteers for project 'Whitecoat' were members of the 7th Day Adventist Church. The 7th Day Adventists were conscientious objectors, but were willing to be incorporated into the army as non-combatants. 7th Day Adventist volunteers were then interviewed and a number selected for the various programmes. In November 1969 President Richard Nixon ended the United States involvement in offensive biological warfare research, after which the US Army's medical research units on biological

warfare are reported to have orientated their work to what would benefit the civilian community, as well as fulfilling a military objective. Much of the research involving operation 'Whitecoat' resulted in publications in the open scientific and medical literature.¹¹

Munitions and Aerosol Dispersion Modelling

For understandable reasons the details concerning some of the warheads and munitions considered for use in a biological weapons context have not been made publicly available. A sequence of three reports indicates the type of assessment that was carried out. The first of these reports¹² includes calculations of area coverage for five liquid agents for use in the E-134 bomblet and three dried agents for use in the 5-inch Flettner bomblet. The payload required for covering a given target area was calculated, as was the appropriate altitude for bomblet release. Calculations were made on the number of bomblets required to achieve 30%, 50% and 70% casualties, assuming that attacks were with uniform randomly dispersed aerosol-producing BW bomblets. Other assumptions used in the calculations were that the target population was in the open and uniformly distributed near ground level; that the population was unprotected; that the meteorological conditions were average; and that the attack took place at night.¹²

The functional characteristics of the E-134 bomblet with three liquid agents and the five inch Flettner bomblets with two dried agents following delivery by a Nike-Hercules missile were assessed.¹³ Certain conditions were assumed but are not specified in the sections of the report made available. The documentation dealt with a preliminary assessment of the biological payload and the likely casualties, the flight characteristics of the missile, and the range limitations.¹³

Similar assessments were made for the Pershing missile nosecone configuration and its possible adaptation for BW use. The E-134 and 5-inch Flettner bomblets with three agents were again assumed to be the mode of delivery. Area coverages of the biological agents were estimated, assuming that the three agents were either disseminated in liquid form from the E-134 or in dried powder form from the five inch Flettner.¹⁴

Increasing sophistication of the modelling of aerosol dispersion is evident in several reports on the BW programme. In one of the earlier reports the author bemoaned the fact that 'intercontinental restrictions on the use of certain agents in large quantities and the size of existing field test facilities automatically limits the scope of this phase' of assessing multiple bomblet in cluster dosage area relationships.¹⁵ The author notes that the information on dosage infectivity or lethality relationships of biological agents with man was 'very scant'. The only way the gap could be bridged was to ask 'experts in the field to venture guesses whose bases are always open to question'.¹⁵

The author noted that adjusting for the degree of protection affordable

to those who might be attacked was difficult to assess. He was hopeful that in a 'relatively short time' the gaps in the data might be filled by a number of carefully designed tests.¹⁵

A model suggested for calculating the number of munitions required for a particular dosage is suggested in another publication that appeared in 1954. The model refines what was described as the TACWIF (Technical Aspects of Chemical Warfare in the Field) method of calculating munitions expenditure. The procedures for the calculation of dosages for a chemical warfare strike were assumed for a biological warfare strike; and adjustments were made for dosages of infective agents over a particular area. The authors noted that the calculations were complicated by the fact that 'the effects of different individual munitions will reinforce each other'. The degree of reinforcement was seen to be a function of the amount of material in any one armament. The weather conditions and the nature of the area to be targeted were also factors to be taken into consideration.¹⁶

A more sophisticated mathematical model for the prediction of casualties in the areas attacked with randomly dispersed anti-personnel biological munitions was reported in 1957. The model takes account of what are described as bomb loading factors (a ratio of the quantity of munitions divided by the dose likely to infect 50% of the population). A series of nomograms allow calculations to be made concerning the likely casualty rates based on various bomb loading factors and the number of bombs dropped. A target area of a particular size was posited and various assumptions made about prevailing meteorological conditions and the decay rate of the aerosol.¹⁷

In 1967 a comprehensive review of the techniques for dosage prediction was produced by the Travellers' Research Center at Hartford, Connecticut for the US Army at Dugway Proving Ground.¹⁸ The 547-page report and accompanying annexe form a comprehensive review of the existing models for assessing the behaviour of gases and aerosols in the atmosphere. The review notes the limitations of particular models and the preference for choosing certain specific examples of these. Limitations with the models available at the time for assessment of the dispersal of agents in the air required further data to be obtained from field trials. More information was required about the diffusion of clouds over particular terrain and vegetation and with a range of meteorological and diffusion parameters. Information was also needed about 'burst cloud sizes, precipitation removal rates, and spray-droplet distribution characteristics of specific munitions'. The models reviewed for aerosols are as applicable to biological agents as they are to chemical agents. However, where biological agents are concerned, there is an additional complication of the time factor as it affects decay of the micro-organisms. The report notes that from experiments in chambers it had been recorded that the rate of decay of the micro-organisms appears to have been approximated 'to a high degree of accuracy by an exponential function'. The report further notes that the

subject of modelling was one of active investigation, but that until a better model was discovered the rate of decay of micro-organisms could be best assessed by the use of a 'simple exponential'.

Defence against Biological Warfare

The need for the deployment of biological detectors is reviewed in two publications made available under the FOI Act.^{19, 20} The second of these references²⁰ incorporates most of the material available in the earlier document.¹⁹ The detection and warning systems calculate the casualties among troops exposed to agents depending on the time when warnings were issued, and the availability of detection systems. The calculations are essentially model systems, and can be adapted to take account of either a cluster of agents being released, or a large volume (for example, from spray tanks). Assumptions were made on the basis of the bacterium which causes tularemia or staphylococcal enterotoxin being released from missiles. Based on the dosage required to affect 50% of the population and the average rate of breathing, calculations were made about the number of troops likely to be affected. The study concluded that proper use of the 'XM 19 detector system should reduce casualties by a factor of about five for agent *Francisella tularensis*' during a simulation of an attack with biological bomblets. Troop training, where taken to a high level, could result in notable reductions in casualty numbers, if detectors were used. In situations where saturation of a target took place, the value of detectors would be much reduced or invalidated completely.

Similar calculations were involved in a threat assessment of the effect of the delivery of biological agent by an intercontinental ballistic missile from the Soviet Union.²¹ The report evaluates the effectiveness of biological agents being carried on the Soviet SS-9 MOD I; the SS-9; the MOD III / IV; and the SS-11 MOD IV intercontinental ballistic missiles. The calculations assume a degree of atmospheric stability and a wind speed of 5msec⁻¹. Assuming an attack on an area some 20 km², with a population density of 5,000 individuals per square km, the report concludes that there would be substantial casualties. The actual numbers of casualties are excised from the report; however the casualty effects in the midpoint of the biological agent cloud released would be considerable 40km downwind and would decrease thereafter. According to the model, casualties might occur as far downwind as 90 km.²¹

Details concerning casualties with a range of biological organisms are available in heavily censored technical data sourcebooks produced by the Deseret Test Centre at Fort Douglas in Utah.²²⁻²⁶ The sourcebooks describe the characteristics of the particular biological agents; the selection and development of particular strains; and the characteristics of disease. Infectivity of the particular organisms (and the toxicity of the toxins) is described and the production of organisms as well as the conditions

necessary for storage and the dissemination from munitions. The predictions of casualty rates are made and estimates of casualties downwind of release. Detection of the agents, protection against them, biological countermeasures and decontamination are also a feature of the technical data sourcebooks. The modelling of the likely casualties following a biological warfare attack indicates a significant improvement in the sophistication of the models available for the assessment.

Threat Analyses

The continental landmass of the United States and both the east and west coasts have been assessed for their vulnerability to biological warfare attack.²⁷⁻²⁹ A study on the Ohio River Valley²⁷ reviewed data on the meteorological conditions in the valley over a period of five years. The report concludes that, on the basis of the results, that account had to be taken of 'a significant number of persistent wind conditions [which] occur in the Upper Ohio River Valley which would be favourable to strategic biological attacks'. The data indicated that there were more than 200 cases of 'persistent wind conditions', which occurred on average during any given year, with wind speeds 'equal to or greater than three knots'. These persisted within a 45-degree sector for seven hours or longer. Noting that there was rainfall for about 70% of the period favourable to biological attack, and that the rain would precipitate out the biological agents, the study concludes that the total number of favourable periods available for attack would be 70% reduced. In other words, there were about 60 spells of persistent wind conditions with no rainfall over the five-year period when a biological attack could be launched.

Two heavily censored documents discuss the biological vulnerability of the United States east and west coasts.^{28, 29} The report on the east coast²⁸ notes that the entire coast is 'typographically ideal for biological attack from land, sea or air'. It describes the meteorology, the climatology and target vulnerability of the east coast of the US. It is noted that before any attack could occur a meteorological study of the target area would have to be carried out prior to any further planning and to observe synoptic conditions in place at the same time. The report goes on to review the travel pattern and dispersal of an aerosol cloud under a number of atmospheric conditions and variable cloud cover at different times of the day and night. The combined population of the 49 metropolitan areas of the eastern seaboard at the time was about 50 million people. According to the report, this figure 'does not include other millions living in the rural areas surrounding the large cities, who are also within striking distance' of any biological agent released in cloud form from the eastern seaboard area. Reviewing a number of ways in which biological attack might take place, and the range of biological agents which might be released, the report concludes that the organism which causes anthrax would be the most

suitable agent for an attack. *F. tularensis*, the cause of tularemia, was the other organism considered, but it would decay at a rate of about 5.3% per minute. Because *F. tularensis* is rapidly killed by sunlight, an attack during the day was not considered to be practicable. The report concludes that down wind travel of an aerosolised load of *F. tularensis* would be limited to between 40 and 50km under 'optimal meteorological conditions'.

The report notes that although a large-scale attack against a civilian population may be of questionable military value, it points out that there is sufficient historical evidence to suggest that civilian targets are susceptible to attack 'even if the reasoning behind the attack appears irrational'. To justify the feasibility of an offshore delivery of a biological agent, the report refers to field trials of the US Chemical Corps in 1952, in which a simulant was released offshore along a 250km line from a ship travelling at eight metres per second close to the South Carolina and Georgia coast. Five trials were conducted, of which one was a failure due to the prevailing wind conditions. The successful trials demonstrated that the simulant cloud could be detected 100km inland and that it had travelled as far as 600km up the coast.

A number of methods of disseminating the agent either from surface ships or from aircraft flying along the coastline are considered. Although the report notes that an aircraft 'would probably be detected by radar' it would not be attacked by US aircraft if the biological attack preceded open conflict and if the aircraft was flying just outside the 12-mile limit.²⁸ (It appears to be inconceivable, however, that an aircraft would be able to follow this flight path without encountering some kind of interception by the United States.)

It is calculated that a quantity of anthrax of the order of 875kg would be required to deliver the median lethal dose of anthrax if it was disseminated along a 100km line and travelled 200km downwind at a wind speed of 4 msec⁻¹. Some 5,000 kilograms of anthrax would be required for a wind speed of eight metres per second. Details concerning the number of casualties in a large area attack have been excised from the report, as have the consequences of an attack on the MacDill Airforce Base, or on Fort Bragg, North Carolina.²⁸ The report concludes that the major metropolitan areas along the east coast of the United States 'cannot be made invulnerable' to biological attack. The report suggests that when biological detectors and alarms are available they should be 'deployed near critical facilities'. For those facilities crucial for national defence it is suggested that biological weapons filters be incorporated into ventilation systems.²⁸

A similar scenario was considered to take account of the biological vulnerability of the west coast of the United States and Hawaii. Once more, anthrax was selected as the agent of choice. The report envisaged the release of 13,000kg of dried *B. anthracis* agent along the north California coast. Delivery was considered to be from a Soviet Oscar submarine which remained 'submerged, with only the outlet pipe of its dissemination

apparatus appearing above the ocean surface'. Estimates were made considering a vessel travelling at 48kmh^{-1} , and remaining just beyond the three-mile territorial limits. The submarine would be tracked by the United States P-3 Orion patrol planes. Because the vessel would be situated in international waters, no attempt would be made to communicate with it. Its mission would not be suspected. For an attack in the northern Californian coastal area the report estimates that of the six million people in the target area, between 55% and 75% would inhale a lethal dose of anthrax within four to five days. (It remains unclear why a nation would want to initiate an attack of this kind and why it would be of the opinion that it could do so without retaliation occurring.) Scenarios for attacks on southern Californian coastal cities and on Oahu in Hawaii have been excised from the report.²⁹

A related report is available on the trichothecene mycotoxins and their potential as 'threat agents'.³⁰ The report computes the quantity of trichothecenes used by 'the Soviets and their allies in Laos, Kampuchea and Afghanistan from June 1975 to October 1982'. A figure of 195,000 kilograms is computed.³⁰ In addition to reviewing the toxicology of the trichothecenes, possible modes of dissemination are considered, together with protective measures and treatment of those affected. The report arrives at some conclusions. Regrettably, the sections of the document dealing with the potential use of trichothecenes as agents of toxin warfare, and the defensive posture of the United States and NATO against the threat posed by these agents, have been excised from the report. From the analysis presented in the report, it is likely that the author concluded that the trichothecenes were a threat. When the allegations concerning trichothecene use in south-east Asia are taken into consideration, together with the 'yellow rain' episode,³¹ the threat analysis of trichothecene is of dubious value, particularly given the overwhelming evidence that the 'yellow rain' was nothing other than the excrement of South East African honeybees.³¹ It is unclear how this analysis influenced US thinking on 'yellow rain' at the time when the report was written in 1983.

Other threat assessments available review the impact of biotechnology in a range of areas, including that dealing with the development of vaccines and biological detection systems. In a heavily censored report³² a number of topics are considered including a range of biological agents; the effects of microencapsulation; 'weaponization'; novel agents; and the activity of the Soviet Union. With reference to terrorist activity, the report notes that there is unclassified information available which would allow the evaluation and production of a number of biological agents to take place 'by individuals with a basic knowledge of the biological sciences'.

Two reports available in 1981 and 1982 respectively^{33, 34} question the value of recombinant DNA procedures (genetic engineering) to produce new biological weapons. The first of these documents is of the opinion that the 'task would be extremely difficult, if not impossible'. The report notes

that once a gene or genes

is inserted into a bacterium, the biological criteria dominate the probability of success, and these considerations indicate that success is unlikely. The questions about matters of virulence, pathogenicity, survival advantage, species barriers (regulation, transcription, translation and transport) lead to the conclusion that the problems preventing success are ones that cannot easily be solved or bypassed.

The report questions whether recombinant DNA research would offer advantages over the known pathogens which are available for bacteriological warfare. Considering the difficulties that would be encountered, the time and the effort required to solve these problems and the low overall probability of success, it is concluded that the value of recombinant DNA research in this field is low. It is also noted that although 'always theoretically possible it appears to be an unrealistic goal. Recombinant DNA research does not offer a reliable approach for the production of bacterial agents that are either novel or superior to those already available.'

The authors were concerned with the interest of Soviet scientists in recombinant DNA procedures. They believed that surveillance of Soviet efforts should be continued. Their view, however, was that the 'possibility of creating a pathogen by recombinant DNA procedures is low'. They also noted that 'more conventional bacterial genetic procedures (e.g. mutagenesis, transformation, transduction and sexual recombination)' are methods that the Soviets might employ more successfully to enhance the virulence of pathogens.³³

Similar views are to be found in a 1982 biological defence study that assessed the biological warfare threat to the United States and reviewed the doctrine, organisation, and equipment of the US medical services.³⁴ This document notes, with reference to genetic engineering, that it is an expensive process and that it would be an 'unnecessary route to BW agents because there already exist many available BW agents which are very effective and give predictable results'. The report does note that a counter argument to this might be the fact that genetic engineering could improve the reliability and control of a BW agent. The document is more concerned with the issue of whether the Warsaw Pact had a BW programme, and it envisaged that a greater threat from recombinant DNA work was not from the development of 'a superior BW organism' but rather from 'the possible production of a cheaper and more lethal toxin'.³⁴

By 1994 concern about biotechnology appears to have crystallized around the ability to produce increasing quantities of existing organisms rather than the ability to tailor make a new product. A 1994 report on biological weapons proliferation mentions that in the United States Army Medical Research Institute for Infectious Diseases³⁵ the view was expressed that while the 'advances of biotechnology extend the producibility of

biological agents, it is important not to overestimate the ability of genetic manipulation to create an “Andromeda strain”. This report further notes that the engineering of infectious agents to render them more infectious or resistant to antibiotics is not a new procedure. The US had developed *F. tularensis* resistant to antibiotics more than 30 years ago using conventional means, without the use of biotechnology. The view was expressed that the risk of another country developing a ‘superbug’ was not very realistic. The greatest impact of biotechnology on the spread of BW capability to developing countries would be their ability to increase significantly the production of previously limited supplies of biological agents or toxins derived from these.

Foreign Scientists

No threat assessment would be complete without a review of the role of the ‘foreign scientist’ who might be involved in biological warfare work. Details concerning some of the principal scientists of the former Warsaw Pact countries have been assembled in a report on the ‘scientific resources for chemical/biological defense’ available to the Warsaw Pact.³⁶ The report details the institutional affiliation of individuals, their research interests and personal history, their known associates, and their publications and patents. Attendance at various conferences is also noted. The report further comments that it cannot list all of the individuals who might have an interest in the subject; but it does concentrate on those ‘known to be involved or highly suspected of involvement in CBW research’. Perhaps some scientists will be disappointed to discover that they are not included in the lists, and believe that they are not prestigious enough or significant enough for inclusion.

Conclusion

The literature obtained under the Freedom of Information Act provides some insight into the working of the United States biological weapons programme. A political system confident enough to release this type of information has to be admired. The documents reviewed in this article are now declassified and available to other researchers who may wish to concentrate on specific aspects of the weapons programmes considered in the literature.

The annual reports of the Chemical Corps¹ allied with reports of the specific operations Big Buzz, Bellwether and Magic Sword provide some fascinating insights into the programme to improve weapons for the delivery of mosquitoes which would transmit yellow fever. The target area for use of yellow fever was clearly the Soviet Union. Information on the stages of this programme provide some insights into the development of a biological munitions system. Other countries considering the use of

entomological warfare would have to follow the same route if they were to develop viable munitions. Of course it is entirely possible that they might attempt short cuts in the process; or they might opt not to use entomological warfare but to rely on dispersal of micro-organisms from munitions or by spray action systems.

The various reports available dealing with the vulnerability of the United States to biological warfare attack present a number of devastating scenarios. These seem to rely on the country being in no position to conduct any realistic defence. It seems highly unlikely that any country would opt to attack the US out of pique. There would clearly be a period when tension would increase, and relations between the US and an aggressor would deteriorate. A period of heightened tension would coincide with increased alertness on the part of the US, and it is unlikely that an enemy aircraft would be able to fly a thousand miles along the coast dispersing a biological agent without its being intercepted in any way. Similarly, a submarine, although travelling in international waters, would be monitored extremely closely. The question comes to mind about some of the threat analyses as to whether they are real, or the acting out on paper of the nightmares of a few individuals. Whilst it is entirely appropriate for the US to consider whether its security could be under threat, it is questionable whether nightmare scenarios help to create a climate suitable for biological weapons disarmament to take place.

A counter argument could be made that a devastating threat assessment would convince the US to continue with its policy to negotiate for a comprehensive biological weapons disarmament regime. The concerns of the country about the inadequacy of the 1972 Biological Weapons Convention are well known. Many of these concerns are set out in a document prepared for the Secretary of Defense prior to the second Biological Weapons review conference in 1986.³⁷ In this year, the principal concerns of the US were that facilities for producing biological weapons could be easily hidden, and that weapons-usable quantities of agents could be produced in a matter of weeks. The potential for a hidden offensive effort using biological weapons could be considerable and any declarations of stocks and facilities are impossible to validate for completeness. In 1986, the US believed that the Soviets may have 'battle-tested in south east Asia'.³⁷ This of course is now known to be unlikely, particularly if it is a reference to the use of trichothecene mycotoxins.

Terrorist use of biological weapons is of growing concern, and particularly in the United States.^{38, 39} The 1995 attack in the Tokyo underground by the Aum Shinrikyo sect, which resulted in the death of 12 people and some 5,000 injuries in the subway system through the use of the chemical warfare agent sarin, sent shivers through the international community. It indicated that terrorists were prepared to use chemical weapons, and the terrorist use of biological weapons remains a possibility. The consequences of such use would have significant consequences for any

government. The threat of non-conventional terrorist attack so worries the United States government, that the Justice Department has distributed equipment and training grants to local fire departments to help them deal with any chemical or biological warfare incidents. A multi-agency operation, code-named 'Poised Response', has recently been established in the United States to co-ordinate reaction to any attack on Washington.⁴⁰

In 1986, as in 1976, the US considered it to be a major shortcoming of the Biological Weapons Convention that there was no way to respond to suspected violations of the treaty. In 1986 the US was not convinced of the ability of an on-site challenge inspection to discover non-compliance. It was equally concerned that, should a challenge inspection take place, that this would have the potential for 'misuse against US technology secrets'.³⁷ However, one way in which these tensions could be eased, and the concerns about biological weapons could be reduced, was for a team to be funded and established immediately to examine the technical aspects of verifying 'agent use and alleged non-compliance'. The team could have national and then international members. It should be capable of swift mobilization and would use protocols and equipment, together with established laboratory facilities and documentation. The 1986 proposals have been realized in the United States at least. The Federal Bureau of Investigation has now established a Gulf Stream-5 long-range business jet to fly specialist teams of agents at short notice to terrorist incidents anywhere in the world. The teams would presumably be able to assess what agent(s) had been used in an accident.⁴⁰ A mechanism such as that introduced by the US also exists for investigating allegations of chemical warfare use under the 1993 Chemical Weapons Convention (CWC). Any CWC investigations would be truly international. An international response to outlaw biological warfare under a revamped treaty with adequate policing powers has to be the next step. Once this has been achieved it is to be hoped that the US will provide resources to support international investigations rather than those led by the FBI – no matter how competent they are.

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Alastair Hay is Reader in Chemical Pathology at the University of Leeds. He has a long-standing interest in chemical and biological warfare issues. He chairs the Working Party on Chemical and Biological Warfare (CBW), a non-governmental organization, supported by the Rowntree Trust, to monitor developments and to promote arms control for CBW. Dr Hay has been involved in two investigations to measure chemical warfare agent residues in soil samples from Kurdish areas in Northern Iraq. Both projects, involved measurements of chemical warfare agents by the UK Chemical Defence Establishment. The investigations established that mustard and nerve gas had been used in Kurdish areas in 1988. Dr Hay has written extensively on the subject of CBW and the need for international treaties to outlaw chemical and biological weapons.

Correspondence: Molecular Epidemiology Unit, University of Leeds, Algernon Firth Building, Leeds LS2 9J.
