RESPONDING TO BIO-TERRORISM WITH THE AID OF HAZARD MODELLING

Alan Jones [1]
Warwickshire County Council – Emergency Planning Unit
Coventry University – Centre For Disaster Management

Keywords: Hazard Modelling, Terrorism, Biological Weapons, Risk, Response

Abstract

Terrorism has for many years been a phenomenon which has shocked the public and challenged the emergency management community. The atrocities of recent years have further astounded everyone with an era of suicide bombers, and the threat of weapons of mass destruction, particularly biological weapons. Although this threat of bio-terrorism is not new, and attacks with conventional weapons are thought likely to predominate, the threat cannot be ignored.

Tackling this almost unthinkable threat is however made more difficult, as there are few historic incidents as a point of reference for risk assessment and planning. In an attempt to bridge this gap, capabilities have been developed known as hazard prediction modelling, which enable the simulation of incidents and their associated impacts.

This paper presents the results from research intended to make an assessment of such capabilities and the improvements offered by their use to emergency management professionals in planning for and responding to bio-terrorism. The paper first examines the nature of the threat before going on to examine current methods of impact assessment / prediction, and the requirements of core responders of hazard modelling, which may be used to inform the future development and enhancement of such capabilities.

Introduction

The number of terrorist incidents has decreased considerably since the 1980's. Yet with attacks like that of September 11 in New York and Washington and the recent London bombs of July 2005, it is clear that this phenomenon is not waiving, and the threat of terrorism remains. In fact despite the number of incidents having halved, the lethality of the remaining incidents has dramatically increased resulting in fifty percent more fatalities (Karmon, 2002) (Barnaby, 2001:17). A further change to the threat is the indiscriminate nature of recent attacks demonstrating an unashamed willingness of terrorists to maim and kill innocent civilians on a mass scale, with almost no consideration for their own lives (Gearson, 2002).

The use of conventional weapons (i.e. explosives), have undoubtedly predominated in recent years with incidents link the Bali, Madrid and London bombings and it is recognised that this trend will likely continue in future. There is however evidence to suggests that terrorists seek

[1] Tel: +44 7712582409
Email: alanbjones@hotmail.com or alanbjones@warwickshire.gov.uk

ever more extravagant and devastating means of terrorism using weapons of mass destruction, which through just their very mention cause anxiety and gain media and subsequently public attention to the objectives of the terrorists, suggested by some to be a keen aim of many terrorist groups (Deshowitz, 2002).

A clear demonstration of the use of such weapons came in March 1995 when the Aum Shinrikyo cult mounted attacks using Sarin on the Tokyo subway (Combs, 2003), which was considered to have "broken the taboo in the use of weapons of mass destruction" (Karmon, 2002:122). Despite the attacks causing wide scale disruption and panic they were considered largely futile due to the primitive and ineffective method of dissemination, demonstrating the difficulties faced by terrorists in the use of weapons of this kind (Dhawan et al, 2001). It is disputed however that with a change from the independent terrorist groups of the 70's and 80's to co-ordinated networks of disparate groups with similar aims such as Al-Qaida, who are able to pool knowledge and resources, initiating such attacks successfully is within closer reach of terrorists.

Biological weapons (defined as "any organism or toxin found in nature that can be used to incapacitate, kill, or otherwise impede an adversary" (Richards CF et al, 1999:184)) have become a increasing focus of international terrorists and dictators over the past 30 years who have been seen to be making continued efforts to obtain and produce them (Hoge, Rose, 2001). The reasons for their appeal being that biological weapons are low cost (in comparison to other weapons), are the hardest to detect and trace, can cause widespread panic and disruption without killing many or any people, and are the most complex to mitigate against and many have the possibility of secondary transmission (Simon, 1997, Karmon, 2002, Granot, 2000). Some suggest (Richards, et al, 1999) that there are however disadvantages to the terrorist from the use of biological weapons including the dangers in producing and handling the agents, though as cited earlier (Gearson, 2002) and demonstrated by many recent attacks including the London Bombings, terrorists have demonstrated that they often have no consideration for their own lives.

The threat from biological weapons was further compounded by the anthrax attacks in 2001 (Curr & Cole, 2002) and several public statements by terrorists since indicating an ongoing interest in the development of improvised biological weapons. This re-enforces the fact that biological weapons are no longer a hypothetical concern confined to fictional thrillers and rare policy discussions (Brusstar, 2002) but that plans and capabilities must be in place to ensure the world is ready to respond.

It is considered the most likely means of distribution by the terrorists utilising biological weapons is the release of the agent into the air as a biological aerosol ("a stable cloud of suspended microscopic droplets of bacteria or virus particles", Simon, 1997:429). Distribution via explosive processes is undesirable because of the likelihood that the organisms will be destroyed during the explosion, and distribution via water supplies is seen to be a less appealing due to the large amount of biological agent which is required mainly because of dilution factors and water purification procedures which extract bacteria (*ibid.*1997). Dissemination of biological agents using aerosols is however not without its problems and in order to be effective the agent particles would need to be refined to 2µm which is a complex procedure requiring specialist knowledge and equipment. Despite this, aerosolisation is considered the most effective means of distribution and depending on the atmospheric conditions could result in clouds of infectious materials carried over hundreds of kilometres.

It is believed that estimation of the dispersal of the material will be a critical element in preparing for and responding to such attacks, though unlike estimations of the impacts of plane crashes which can be made based on passenger and crew manifests, estimating the plume of hazardous materials is much more complex. Such hazardous areas can be defined however using a concept of Crisis Prediction (hazard modelling), which has gained appreciable momentum in recent years and which enables the identification of hazardous areas such as those created following a biological release (Swiatek & Kaul, 1999).

Hazard models are tools, which enable probabilistic prediction of hazards, represented on a rectangular grid (X, Y) (Hunting Engineering, 2000). In order to create such models input files are required which describe the circumstances of the hazard i.e. what, where and when. Through the use of complex particulate transport equations it is then possible to produce hazard files, which define the hazard 'footprint' or 'template' (Hunting Engineering, 2000, & Science Applications International Corporation, 2002a/b). This output can then be manipulated in conjunction with other grid format files (databases) to analyse the hazard further.

Hazard modelling is predominantly used as a decision aid for consequence management following the immediate onset of disasters. It also has the capacity however, to be used in other practical applications in emergency management including contingency planning, validation of emergency response plans, training, exercising, and post incident evaluation.

This paper presents the results from research, which seeks to evaluate these models and to identify how they may be utilised to assess the risks and the impacts of a biological attack on an unprotected civilian population. Conclusions will then be drawn on how these models may improve the effectiveness and safety of response should such a threat become reality.

Theory and Method

Research began with an extensive literature review to identify the vast arsenal of biological weapons, which are obtainable, their most probable forms of dissemination and their impacts on unprotected populations. This literature review also sought to review existing hazard modelling environments which are being developed or which are in current use, and any studies relating to their offered improvements to disasters involving biological weapons.

Secondly a number of questionnaires were distributed to core responders identified as having a role in preparing for and responding to a CBRN incident in the UK, according to strategic national guidance. This element of the research sought to identify current adoption and awareness of hazard modelling, alternative / current means of impact assessment and desired user requirements and attitudes towards hazard modelling.

Finally using the information gathered during the literature review it was possible to generate a number of probable scenarios, which could be simulated using hazard modelling to evaluate the benefits and performance of current capabilities, and potential uses of their output. This was also important in corroborating the responses from the questionnaires.

The model chosen for this experimentation was based upon its applicability to model a bio-terrorist incident in the United Kingdom, its reputation and positive reputation of verification and validation. The final consideration and one, which was considered to have significant influence for the end user, was finance.

Based on this information one such model was identified, the Defence Threat Reduction Agencies, Hazard Prediction and Assessment Capability (HPAC). A forward deployable, Nuclear Biological and Chemical (NBC) hazard prediction capability, which is stated to accurately predict the effects of a hazardous material release into the atmosphere and evaluate the subsequent collateral impacts on the civilian and military populations.

The software uses integrated source terms, and an array of terrain, land-use and meteorological data (i.e. climatology, high resolution weather forecasts and real-time observations), and particulate transport algorithms to model hazard areas and human collateral effects in minutes. Its use is designed for both operational users (i.e. those users responding to actual or expected events) and analytical users (i.e. those involved in research and development). (Science Applications International Corporation, 2002a).

Results

The literature review identified up to seventeen hazard modelling capabilities able to simulate the dispersion of biological agents used as weapons. Despite such capabilities being available and widely used in the United States however, adoption in the UK was limited to just one quarter of those involved in the questionnaire. Furthermore current means of consequence assessment were considered largely inadequate with respondents to the questionnaire citing either blind estimation or reliance on others with no obvious pattern or justification for their response. This is considered to largely be the result of a misunderstanding of the roles and responsibilities of those authorities resulting from confusing and sometimes conflicting guidance.

Despite limited adoption and even awareness of hazard prediction modelling significant interest was expressed as to its potential to assist in planning and responding to incidents of bio-terrorism, though its use as identified during the research has both advantages and disadvantages.

<u>Advantages of Hazard Modelling</u>

The advantages were many and varied throughout the disaster cycle, identified below:

1) Preparedness Planning
The importance of risk assessment and the need for planning, which is soundly based upon it is vital if the authorities are to ensure the adequacy of plans and capabilities to respond. Though with little known experience of bio-terrorism, it is difficult to assess the risk or plan logistics for such an eventuality if it is not possible to estimate the likely consequences. With the advent of hazard prediction modelling though it is possible to develop worst-case scenarios on which to assess vulnerability and assess potential response requirements, including decontamination and adequate stockpiles of antibodies for treatment.

2) Training and Exercising
In addition to having sound plans in place for a bio-terrorist attack, implementation and monitoring of these is essential and is achieved through training and exercising. Though again visualising this almost unthinkable threat can be difficult.

Hazard modelling provides trainers and those preparing exercises with a platform on which they have the ability to create illustrative scenarios, with tangible materials for those involved creating a greater sense of realism, increasing the chances that those involved will gain an accurate understanding of the challenges faced. Furthermore hazard modelling enables numerous scenarios to be created developing broader thinking of those being trained of the likely responses required and more comprehensive testing of procedures under various scenarios.

3) Response
Once a biological attack is suspected it is important that steps are taken to determine exposure risk, and the potential effect[s] to define the needs from both local and national resources. Identified in the research as the phase in which questionnaire respondents would find hazard modelling most useful, during the response phase there are numerous benefits of the use of hazard modelling perhaps most crucially the protection of life and to do this it is vital to

provide adequate warning and advice to members of the public. By using hazard modelling it is possible to estimate the likely spread of the agent in the atmosphere and from this develop strategies for evacuation or shelter, and determining areas where responders would need to use personal protective equipment.

Early assessment of the impact will allow specific, targeted and prompt treatment, and provide a greater window of opportunity during which prophylaxis by response agencies and the public will be more effective and thus save lives (Simon, 1997). It is commonly recognised there is a need for better strategies for mobilising and co-ordinating the vast resources which would be required to respond to a bio-terror attack, increasingly important as extensive pressures are likely to be placed on these.

Hazard modelling will enable rapid forecasting of contaminated areas and determination of where these would be most appropriately and effectively deployed, for instance those most likely to benefit from medical intervention, or those who require immediate isolation if any secondary contamination is to be contained. By using these estimations it will also be possible to identify potential number of casualties so as to identify appropriate hospital space, and mortalities so that appropriate mortuary arrangements can be put in place.

Using the output from the model it may also be possible, with interrogation of underlying Geographic information, to identify and evaluate the secondary hazards of the release. For instance if the bio-plume crosses a freshwater reservoir which serves the local population with drinking water then it may be necessary to restrict this source until it is tested for contamination.

Finally in the longer term mitigation of the impacts hazard modelling can assist by providing damage and loss assessments, such as those areas, buildings and critical facilities, which will likely be inaccessible due to contamination, and also be used to inform the longer term economic consequence assessment.

4) Post Incident

The importance of isomorphic learning (Toft & Reynolds, 1997) cannot be underestimated if future improvements are to be made to response tactics, and be better prepared for such disruptive events as a bio-terror attack. Hazard modelling assist in this endeavour by allowing the incident to be re-created allowing decisions to be evaluated and lessons learnt.

<u>Disadvantages of Hazard Modelling</u>

Despite the many benefits of hazard modelling there are also a number of uncertainties, some significant to suggest that current technologies are not adequate to support such rapid and dynamic response.

1) Reliability and availability of data

Firstly the output created from such models is clearly only as good as the input data used for their calculation. The research revealed that the reliability and availability of input data required for such modelling is questionable. Foremost is that by its very nature terrorism is unpredictable and with a biological attack likely being covert, may go unrecognised for hours or even days, and with hazard modelling reliant on real time information this immediately negates its use. The only way it is thought such information and intelligence could be obtained is through use of air sampling devises, though these would be dependant upon their strategic placement, and would also be extremely expensive.

As well as the user input information the reliability of the incorporated data of such models was found to have inconsistencies when compared with other data sources. Firstly in the case of population data there appeared to be no consideration for variables such as night and day population migration known to illustrate significant differential in major cities, furthermore at a national level, population numbers varied between data sets compared by up to two million, though comparability at a sub national level was much more accurate.

Location inconsistencies where also identified as a problem as numerous co-ordinate systems are being used across the world, some seeing the world as spherical, some flat and some based on one continent alone. The result is that the co-ordinates of a location may not match in each case. Scalar differences of these inconsistencies ranged from 0.7 km to 11.4 km.

2) Reliability of Models and Output

Despite this, general option of those involved in the research revealed the considered reliability of such models was good. In fact such models as that used in the research have undergone extensive validation and review with the developers claiming they are more than ninety percent accurate. The experiments carried out also supported this with close comparability with other estimates, though the question remains as to the accuracy of any such prediction until there is a measurable CBRN event occurs and such predictions remain speculative.

The reliability of the output from such models is also questioned as many of the models base consequence / impact assessments i.e. casualties / mortalities, on the likely collateral affects on fit military males. Considering the normal composition of the average society including elderly, infirm and the young the resulting consequences could be worse than estimated.

In addition those models identified during the research appeared to have no consideration of the likely impacts of population dynamics, particularly important where the agent released has the potential for secondary ‘person to person’ transmission.

3) Resource Demands

In addition to the disadvantages noted already a particular reason why hazard modelling may not be widely adopted in the UK as cited by questionnaire respondents is the demand they place on resources both financial and physical (i.e. workforce).

Firstly the cost of procuring such models is considered to be high, and with the exception of HPAC used in this research and available free of charge, with a government sponsor, many of those models found to be available cost several thousand pounds.

It is also considered that a great deal of expertise is required to operate such models requiring significant training time for staff. The research revealed that extensive training materials where available to enable in house training saving time, though to attain an adequate level of proficiency level to operate and understand the output took considerable time.

4) Model appropriate risks

The final key disadvantage of current hazard modelling capabilities considered their ability to model appropriate and current threats.

Firstly all models evaluated as part of the research had only the ability to predict the consequences of a malicious release of a biological substance into the open air. Conversely it is as likely that terrorists will initiate such attacks within buildings or enclosed environments such as the London Underground, demonstrated by the attacks on 7th July as a target of terrorists. It is known however that such capabilities are being developed for the future.

Secondly although it is recognised that the threat of bio-terrorism remains, it must be understood that the targets and consequences may not always be humans, and may in fact be crops and livestock i.e. agro-terrorism, which could create scenes similar to the foot and moth outbreak of 2001. Current hazard models found during the research do not have the capability to model such impacts, which should be considered.

Specification for the Future

The research has established that hazard modelling may aid the response to a bio terrorism incident though there are also many difficulties faced through its adoption, and areas in which improvements are required. Those involved in the research identified the following abilities of future hazard prediction modelling capabilities, which were desirable:

1. Hazard area display Incl. measure of uncertainty
2. Ability to predict likely casualty rates
3. Ability to predict likely mortality rates
4. Ability to evaluate various counter measures e.g. evacuation / shelter
5. Ability to determine personal protective equipment requirements
6. Consideration of the effects of population movements on any possible spread
7. Ability to evaluate long term impacts (e.g. environmental, economic & social)
8. Ability to model the impacts of releases in confined / enclosed spaces

Conclusions & Recommendations

Adoption of hazard prediction modelling is low in the UK and current methods of prediction / consequence assessment largely inconsistent. Strategic national guidance of CBRN response does not however clearly establish with whom responsibility for such assessments will rest, and this results in an inconsistent and inadequate response. It is therefore recommended that there is a need to:

- Clarify roles and responsibilities and promote a co-ordinated approach to initiatives relating to hazard modelling following CBRN incidents.

The research found that despite the uncertainty of responsibilities there were a number of planning and operational requirements, which could not be met with those assessment techniques currently used, particularly the ability to estimate the physiological effects of a bio-terror attack. Though despite this understanding of the need for information of this kind adoption of hazard modelling in the UK is limited, perhaps as identified during the research because of a lack of awareness and understanding of hazard modelling. Furthermore the vast array of seemingly competitive modelling capabilities, makes any choice difficult unless people are aware and understand their strengths and limitations. It is therefore recommended:

- Training and awareness be developed and delivered to highlight the strengths and weaknesses of hazard modelling capabilities

- A central point be established where emergency managers may receive impartial information and comparison of the available modelling capabilities.

Comparison of user requirements with current capabilities however identified various needs which were unsatisfied illustrating a need for further research and development. It is realised that the development of a ‘perfect’ hazard prediction capability may be some way off though it is felt with greater co-ordination of developments, this will be made easier. In fact it is understood that research continues regarding the development of capabilities for use in the UK, by government and the military, though much of this is appears to be done in isolation and without fully considering end user requirements. It is therefore recommended that:

- Both national and international working groups on consequence / hazard modelling be set up to united researchers and developers from the public and private sectors, academics, emergency management and response professionals and other relevant experts to co-ordinate the future developments in a comprehensive and co-ordinated manner.

In addition to the models themselves it has been identified that a number of uncertainties exist relating to the supporting data for such capabilities. As with the hazard models themselves however users are faced with a confusing array of sources for the data to support such calculations. It is recommended therefore that:

- A comprehensive study of data capabilities and limitations is undertaken by an independent body to ensure that those using them can be assured of their accuracy and appropriateness, and where there are deficiencies these be addressed.

The uncertainty involved in modelling biological releases is clearly evident in relation to the data used but the underlying methodology and algorithms are also an important consideration. Full analysis of these was neither within the remit nor capabilities of this research as they concern detailed mathematical models, however the information, which informs them, has been highlighted by the research as a cause for concern.

Atmospheric dispersion clearly is not an exact science and as, illustrated earlier in the paper a number of external factors influence the behaviour of any plume. When considering the likely impacts of a biological release however there are added uncertainties. Firstly with little know experiences and data available in relation to such terrorist incidents in the past there is little opportunity to evaluate the resulting outputs. Furthermore impact assessments in many of the models available appear to be based upon the effects on young health military males (Defence Threat Reduction Agency, 2002). This clearly does not illustrate the demographics of the average UK community, and thus the impacts experienced could be significantly different. Based on this it is felt important to recommend that:

- Clear information be given to emergency responders and managers to ensure they have a realistic understanding of the uncertainties involved in modelling predictions and the variability to be considered.

In relation to this uncertainty factor is the ability of existing hazard modelling capabilities to consider the current threats posed by terrorist, and thus meet the requirements of the emergency community. For instance all of the models evaluated as part of this research were found to have a limited range of biological agents to choose from, including those known to have been considered by terrorist groups. Furthermore the ability of the models to accurately predict releases in areas, which are thought to be, and suggested by terrorists as targets such as urban and enclosed (e.g. buildings, underground transport system) environments is limited.

Urban environments particularly have complex local topography, which lead to local wind patterns carrying the contaminant in unexpected directions. Many of the hazard modelling capabilities are known to based on a 30m building canopy which clearly does not represent major cities in the UK or the rest of the world, and therefore pay little consideration to such meteorological phenomenon, which could lead to inaccurate assessments (Beriwal & Merkle, 2001). Secondly in relation to the considered release of biological releases within enclosed environments such as underground transport networks as was demonstrated by the 1995 Sarin attacks in Tokyo (Fountain, 2002), very few capabilities exist and little research is known to have been conducted in relation to the airflow patterns in such environments. It is therefore finally recommended that:

- Consideration should be given to developing profiles within existing models for an extended list of agents, including those which are naturally occurring but which could be adopted as weapons (i.e.influenza).

- Further research to characterise the local wind flow patterns in urban areas, and enclosed environments to inform the development of appropriate modelling capabilities.

It is important of course to tackle the causes of terrorism at the root, but terrorism is an ever-evolving phenomenon and one, which it may not be possible to eradicate. It is though also impossible to estimate the precise likelihood of a terrorist attack involving biological weapons, though clearly the threat cannot be underestimated. Consideration must be given therefore to whether full use is being made of science and technology to counter these threats, technologies like hazard modelling.

"It is a significant challenge to prepare for an unknown event" (McFee, 2002), but it is the unknown to which the world is most vulnerable. Hazard modelling, is one way in which this unknown can be simulated and through this enable the preparation of more robust plans and response strategies. Clearly the capabilities developed to date have some way still to go though, as previous studies have shown a favourable interest exists in hazard modelling amongst the emergency planning community (Amat & Athwal, 2001). Despite this however efforts to provide such capabilities for the emergency management community in the UK, have been thwarted by lack of funding and restructuring of services. It is now vital that partnerships be built and a co-ordinated and consistent approach taken to ensure preparations are put in place to for asymmetric attacks such as those involving biological weapons, to address the resource and information gap, which exists.

References

Amat G & Athwal S, (2001) *HAZMOD Intranet Pilot: Summary Report of Results*, Civil Contingencies Secretariat, London

Barnaby F (2001) *Waiting for Terror: How Realistic is the Biological, Chemical and Nuclear Threat,* Oxford research Group, USA

Beriwal M & Merkle PB (2001) *Defence Threat Reduction Agency CB Modeling and Simulation Futures Workshop,* Advanced Systems and Concepts Office, USE

Brusstar G (2002) Bio-terrorism, Yesterdays Threat, Today's Reality In: *Michigan Medicine*, Vol. 101, No.1, pp 18-21

Combs CC (2003) *Terrorism in the Twenty First Century, 3rd Edition,* Prentice Hall, New Jersey

Curr N & Cole B (2002) *The New Face of Terrorism, Threats from Weapons of Mass Destruction,* I.B Tauris Publishers Ltd, London

Dershowitz AM (2002) *Why Terrorism Works, Understanding the Threat Responding to the Challenge,* Yale University Press, New Haven

Dhawan B, Desikan-Trvedi P, Chaudhry R & Narang P (2001) Bioterrorism: A Threat for which we are ill prepared' In: *The National Medical Journal of India,* Vol.14, No. 4, pp 225 – 230

Defence Threat Reduction Agency (2002) HPAC 4.0.1 *Basic Operator Training* [Training Materials] DTRA, VA, USA

Fischer H.W. (1999) Dimensions of Biological Terrorism: To What Must We Mitigate and Respond? In: *Disaster Prevention and Management,* Vol. 155, No 2, pp 27-32

Fountain R (2002) *Anthrax Tested on London Tube* [Online] Available from: http://news.bbc.co.uk/i/hi/world/americas/1843181.stm [26 February 2002]

Gearson J (2002) *The Nature of Modern Terrorism,* Blackwell Publishing, Oxford

Granot H (2000) Planning for the Unthinkable: Psychological Reaction to Chemical and Biological Warfare (CBW) Weapons In: *Australian Journal of Emergency Management,* Vol. 15, No. 3, Spring 2000, pp 21-24

Hoge JF & Rose G (Eds.) (2001) *How Did This Happen? Terrorism and the New War,* Public affairs Ltd, Oxford

Holloway HC, Norwood AE, Fullerton CS, Engel CC, & Ursano RJ (1997) The Threat of Biological Weapons, Prophylaxis and Mitigation of Psychological and Social Consequences, In: *Journal of the American Medical Association (JAMA),* Vol. 278, No. 5, pp 425 - 427

House of Commons Defence Committee (2002) *Defence and Security in the UK,* The Stationary Office Limited, London

HPA (Health Protection Agency (2003) *Research and Development,* [Online] Available from: http://www.hpa.org.uk/about_us/randd.htm [accessed 29/04/03]

Hunting Engineering (2000) *Hazmod 32 Users Manual,* Hunting Engineering, Bedford

Karmon E, (2002) The Role of Intelligence in Counter Terrorism, In: *The Korean Journal of Defence Analysis,* Vol. XIV, No 1, pp 119-139

McFee RB (2002) Preparing for an Era of Weapons of Mass Destruction (WMD) Are We There Yet? Why We Should All be Concerned. Part 1, In: *Veterinary and Human Toxicology,* Vol. 44, No. 4 pp193-199

McGee MK, (2002) A prescription for Millions In: *Information Week,* Issue 885 , pp 70-73

Richards CF, Burstein JL, Waeckerle JF, & Hutson HR, (1999) Emergency Physicians and Biological Terrorism, In: *Annals of Emergency Medicine,* Aug 1999, Vol. 34, No 2 pp 183-190

Science Applications International Corporation (2002a) *Hazard Prediction and Assessment Capability (HPAC) User Guide Version 4.0.1,* Defence Threat Reduction Agency, Virginia

Science Applications International Corporation, (2002b) *CATS-JACE User Manual, Version 1, Build 81,* Defence Threat Reduction Agency, Virginia

Simon J.D. (1997) Biological Terrorism, In: *Journal of the American Medical Association,* Vol. 278, No 5, pp 428-430

Swiatek JA & Kaul DC (1999) *Crisis Prediction Disaster Management* [Online] Available from: http://www.saic.com/products/simulation/cats/VUPQPV4R.pdf [January 17 2003]

Toft & Reynolds (1997) *Learning from Disasters: A Management Approach*, Perpetuity Press, Leicester

Acknowledgements

I would like to express my thanks to Mrs Eve Coles and Mr Robin Tasker for their support and assistance in the preparation of this paper. I would also like to thank the Defence Threat Reduction Agency and their staff for providing me with the software and support to conduct this research.

Author Biography

Alan is currently an Emergency Planning Officer, for Warwickshire County Council in the UK, where he is responsible for various aspects of emergency management ranging from risk assessment, business continuity, mass fatality planning, and the development & use of GIS across the work area.

Alan has a Bachelor of Science (BSc Hons) in Development and Health in Disaster Management (2002) and has recently completed his Masters degree (MSc) in Disaster Management at Coventry University – Centre for Disaster Management, researching the use of hazard prediction modelling to improve planning and response to bio-terrorism in UK.

In addition to Alan's current role he has also worked in Emergency Management across all levels of government in the UK. Firstly central government (Home Office – Emergency Planning Division) where he worked as part of the scientific research group developing hazard modelling, and other areas in support of EPD objectives. The findings of which were ultimately disseminated and used in the development of effective national arrangements for integrated emergency management. Alan has also worked for the Government Office for the West Midlands where he was seconded to assist in the development of the largest live CBRN exercise to be held to date in the UK.