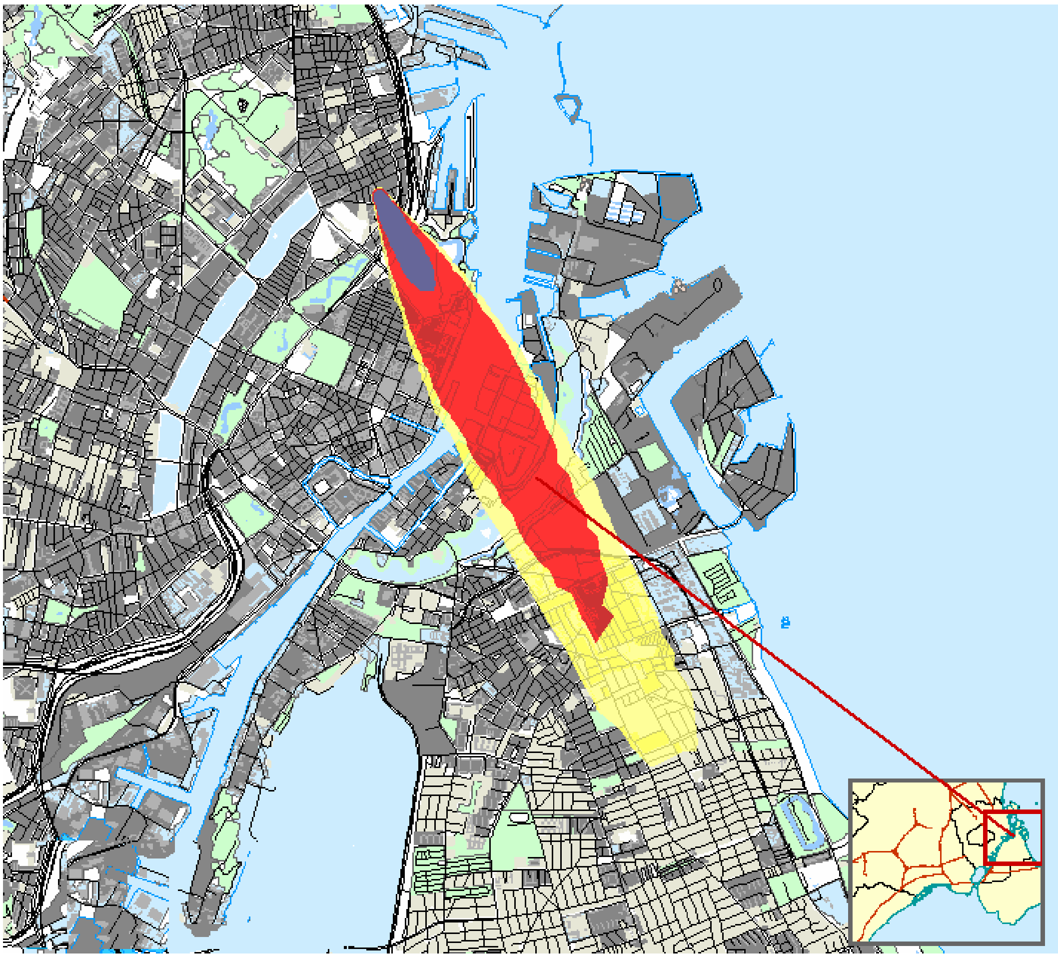
Biological Incident Response:

Assessment of Airborne Dispersion



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PREFACE

The reported work has been supported by the European Commission under the project "EU Co-ordination and Dissemination of Strategic **Mo**delling Capabilities to Help in Public Health Contingency Planning/Preparedness/Policy for and Mitigation of the **Del**iberate **Rel**ease of Biological Agents" –MODELREL, research project under the European Commission's Health and Consumer Protection Directorate General, Grant Agreement no. 2003206 . This report was prepared by the National Centre for Biological Defence, Artillerivej 5, DK-2300 Copenhagen.

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1. Abstract

Bioterrorism is the deliberate release of a pathogenic organism, bacteria, virus or toxic substance with a biological origin. Dispersion in open air could be an effective method to inflict mass casualties and to expose large areas to hazardous material. It may well not be possible to detect the area immediately, which is why mathematical modelling will be a helpful tool to recognise the size and geographical position of the contaminated area. Some of these models have been developed into operational systems that are able to perform calculation in a timely fashion to support response managers and decision makers to employ appropriate countermeasures.
The present report will describe some specific implementations and specifications of such systems that in whole or in parts may be applicable for response units in Member States.

Visualisation of the position of an affected area in the form of contours with varying degree of concentration can be presented on a map and used for real time response, for pre-event planning and for post-incident assessment. An operational dispersion calculation system can provide first responders, sampling teams, police, health officials, incident commanders and decision makers with critical information on which relevant life saving countermeasures can be based. Countermeasures; including evacuation, cordoning off contaminated areas, positioning of command posts, decontamination and implementation of medical countermeasures (medication and vaccination), should to be based on dispersion assessments. This is especially true for biological incidents, where the hazardous area cannot be immediately identified.

State-of-the-art dispersion calculation systems include models for release type. The release type is the means of delivery (“weapon”) e.g. munitions, improvised dispersion devices such as sprayers or letters. Models for down wind dispersion incorporate algorithms, and take landscape, landuse and weather parameters into consideration. Furthermore, the number of persons at risk and casualties can be

modelled, should demographical data and a bio-data base including information on lethality, be available.
These are the core capabilities of a decision support tool.

Chapters 2-4 describe components of a biological response unit, the setting in which it manoeuvres, a scenario to illustrate the iterative process, using a dispersion calculation system for support, followed by examples of derived recommendations. The latter chapters deal with the systems: a specification of what components a system should consist of, including models and input data together with a description and evaluation of four available systems.

After reading this report, the reader should be able to understand the use of a decision support system for airborne releases, how they improve response capabilities, and how to establish contact to system developers.

2. A specialised biological response support unit

Responding to a biological release requires a range of general response capabilities, of which the major part is generic preparedness capacities from police, health and emergency services. A core capability is, however, also a specialised support unit for investigation and dispersal assessment. Such a support unit needs to have the following separate capacities:

Medical intelligence assessment (referred to as MIA) plays a key role during the initial stages of a biological incident. Initially, the information on which to base the initial dispersal and hazard assessment comes from intelligence sources and an updated situational awareness of current threats. A specialised biomedical expertise concerning biological weapons is needed to assess the intelligence and decide what course of action to take, and also provide the dispersal assessment unit with estimates of release parameters such as agent and amount. As the incident evolves, this expertise will be applied to all incoming information as the background threat assessment is qualified by empirical information from on-scene observations and laboratory analysis.

Coordination of operational and medical assessment (referred to as COMA) is required to ensure coordination of the investigation with the purpose to identify the threat and relevant countermeasures in time for the attack to be mitigated. This coordination involves input from intelligence and dispersal assessments, field investigation teams, and laboratory analysis, and the COMA unit supplies consolidated recommendations to the on-site incident commander, and other authorities responsible for the overall incident management. The information provided by the COMA unit should eventually include identification of the agent, definition of the dispersal area and persons at risk, a prognosis for the immediate consequences and recommendations for relevant countermeasures. This coordination unit also has responsibilities for the logistics involved in the field investigation, including arrangements for samples and other evidence to be transported and analysed at appropriate facilities.

Field investigation teams (referred to as FIT) are required to investigate a suspected area of release, gather information from objects at the scene and collect relevant samples for subsequent laboratory analysis (EU-guidelines[1]). The main purpose of a field investigation is thus to provide data to qualify the dispersal assessment and obtain material to identify the agent. A FIT capability includes biomedical expertise specially trained in CBRN issues and with experience in forensic crime scene procedures. As they are working in the hazard area, the teams must use personal protection. During the mission the FIT commander exchanges information with the COMA unit and a mission concludes with transport of samples and evidence to relevant facilities.

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[1] Biological Incident Response & Environmental Sampling - Guideline from the EU Commission 27 OCT 2006. available at www.bioberedskab.dk and at http://ec.europa.eu/health/ph_threats/com/preparedness/docs/biological.pdf. Accessed January 2007.

3. A bioterror scenario and response

Identification of an affected area, following an open air release, is the first step towards being able to respond appropriately. To identify this area, a model can be used, in which the minimum input is data on where and when, the amount of agent that has been released, and preferably what kind of agent is used. The earliest available information is likely to be descriptions from witnesses and police reports, which along with intelligence information will be the basis for the preliminary dispersion calculations. During field investigation, new information will become available and can subsequently lead to changes in dispersion calculation estimations.

To illustrate the complexity of the response to an overt biological attack, and to obtain an understanding of how a wind dispersion calculation system is used real time, a scenario is outlined below.

At 08:30 in the morning, a letter containing powdery material is opened in the postal facility of an international organisation. The organisation contacts the police half an hour later, and after 15 minutes the police arrive, making a preliminary investigation of the place. The police decide to withdraw from the scene and to request support from a bioterror response unit.

- 10:00 The MIA officer in charge at the bioterror response centre is contacted by the police to discuss the available information' matching intelligence with threat characteristics. Because of a written threat included in the letter, and because of the physical appearance of the powder, matching that of known bioterror agents, it is decided to deploy the FIT and the COMA unit.
- 10:20 The COMA commander activates the FIT leader, who alerts the three other team members who arrive at the bioterror response centre within one hour.
- The COMA unit obtains the necessary external input data for a dispersion calculation from contacts at the scene (police, fire fighters and witnesses) to run the initial dispersion calculation. Numerical weather data files are down-loaded from national meteorological institutes and from global weather information servers.
- 10:45 While the FIT personnel are arriving at the bioterror response centre, the initial dispersion calculation, based on *Bacillus anthracis* is being modelled to support FIT for planning of sampling strategy: direction of arrival without crossing potential contaminated area and establishment of a hotline between contaminated and clean area, where the FIT command post will be set up.
- 10:56 Wind dispersion calculation results are communicated to police at the scene to be disseminated to other rescue teams involved in the incident. The dispersion calculation result (see example in chapter 10) is used by the police and others to establish a cordon sanitaire, evacuation routes out of the contaminated building and nearby buildings.

10:00 The MIA officer on duty is contacted by the police.

10:20 The COMA unit is established and activates the on-call FIT. COMA informs time, place and nature of the attack.

10:22 The MIA officer requests dispersion predictions from the dispersion expert in the COMA staff in order to plan the FIT mission.

10:50 First preliminary dispersion calculation is completed to be used for planning of the field investigation strategy.

10:54 Request to civil defence unit to establish decontamination facility on-site.

10:56 Dispersion results are handed over to the police to be used as guideline for on-site management.

- At a safe distance (defined by the dispersion calculations results) from the point of release, police and civil defence establish a perimeter around the point of release, a command centre, a decontamination facility etc.
- COMA commander monitors all activities through established secure channels. Information goes out to relevant alert systems in the EU.
- 11:35 After planning sampling strategy in detail with input from COMA (including dispersion calculations) the FIT team leaves the centre.
- 12:40 FIT crosses the hotline, wearing full personal protection. After investigating the letter, the team estimates the amount of spilled powder to be a few grams, and that it was expelled from the building from 5 meters above ground level. Photos from the room where the letter was opened are transmitted to the COMA dispersion experts, indicating that release through ventilation ducts may have occurred. The dispersion calculation is upgraded with the new data. The input to the dispersion calculation system is run with 1 gram of anthrax.
- The wind dispersion results are also used in the estimation of potential number of casualties. Hospital treatment capacity is evaluated in relation to the number of people to be expected for treatment during the outbreak period. These estimations are communicated to public health officers.
- In addition to the dispersion calculation, the resulting plume is analysed in a geographical information system (GIS) where places of special interest (POI) within the plume are identified, i.e. buildings with a high number of people such as schools and work places with many employees, as well as institutions with special relation to the civil defence: medical laboratories, hospitals, governmental buildings etc. This information is communicated to incident managers.
- 14:40 The FIT finishes the sampling and samples are transported to a BSL4 laboratory.

11.35 FIT leaves the centre to arrive at the scene 25 min later.

12:45 FIT reports from the scene that it is likely that material has dispersed to the exterior through a ventilation duct.

13:15 Calculations with an increased amount of agent expelled to the exterior, results in an enlarged affected area. The estimated area is now approximately 2x1 km including a day-time population of 8000 people. (See box 1)

13:30 Adjusted dispersion assessment is circulated to response managers who will adjust interventions accordingly.

15:30 The adjusted time for opening of the letter leads to download of new weather files and results in a slightly changed position of contamination, but of approximately the same size, encompassing the same number of PAR. New maps are circulated.

- 15:00 New information is received about the time of opening the letter which is reported to have happened almost an hour earlier than initially assumed. New weather files are downloaded matching the new time of release. The resulting plume covers a slightly larger area and diverts about 15 degrees resulting in a new estimated area of contamination which contains a number of places of special interest not formerly included. The calculations show more casualties due to the larger plume and lower UV degradation of the agent in the early morning with less influx of UV.
- 20.00 The BSL4 laboratory reports that analysis has begun.
- 00:20 The laboratory reports that the size of the organisms in the material is more like that of smallpox. This results in a new dispersion calculation with the specification of the *Variola major* virus. Results (area, PAR and casualties) and new recommendations are communicated.
- 03.10: The laboratory reports that the PCR analysis rules out *Variola major*. The dispersion calculation is changed back to be based on *B. anthracis*.
- 04.30: The laboratory reports that PCR shows presence of *Bacillus sp.* and the formerly produced dispersion calculation based on one gram of anthrax is maintained as the basis for further recommendations.
  Toxins have not been ruled out by the laboratory and a dispersion calculation based on ricin is performed. The calculation shows that there is no dispersion to the surroundings with the estimated amount. Should the agent turn out to be ricin only the people who have been in close contact with the powder will potentially develop ricin poisoning.
- In the following hours, the BSL4 is analysing the purity of the agent in the sample to be used for adjustment of the dispersion and PAR calculations.

12:00 Output casualty estimates are entered into a modelling tool to calculate resources and man-hours required during a medication dispensing campaign.

18:00 Laboratory analysis results of the environmental samples are returned from the BSL4 to the COMA unit which in collaboration with dispersion experts adjust the iso-dose contours of the dispersion calculation. The contaminated area is reduced because of lower concentrations than expected. New PAR and casualty estimates .

19:00 New recommenda-tions are communicated, based on a smaller contaminated area.

01:00 Dispersion calculation based on smallpox resulting in new PAR and fatality estimate.

08:00- .After Bacillus sp. *has been found in the samples the suspicion of the powder being a live agent and not a hoax is strengthened and laboratory analysis is intensified.*

Box 1. To exemplify the extend of a realistic deliberate release of dry anthrax delivered by means of a letter, calculations made by a wind dispersion assessment system estimate that about two thirds of the very fine powder could become airborne just from opening the letter. This would result in the release of one trillion (10^12) spores with a potential of causing 125.000.000 (one hundred and twenty-five million) deaths. Due to thinning in large volumes of air, a not uniformly dispersed population and due to biological decay, a dispersion calculation system estimates a two kilometre long egg-shaped plume where people have a risk of being infected, potentially causing 1.700 deaths.

4. Derived recommendations based on output from dispersion modelling

In the aftermath of a positive laboratory analysis, the COMA unit produces a number of recommendations, some of which are based on different modelling tools. In this chapter, it is described how dispersion calculation results are used in dimensioning prophylaxis campaigns, analyse impact on public health facilities, forecast number of expected cases in the immediate future, and to validate dispersion results.

4.1 Prioritisation of medical stockpiles

To efficiently administer a limited amount of medicine and vaccine, or if treatment is connected with risk due to medical side-effects, prioritisation of people who are to receive treatment must be made. This prioritisation takes into account both the scientific basis and the particulars of the situation, i.e. a threat to national security.

Estimation of the number of casualties is a product of the number of people who have acquired an infectious dose and the dose response for humans. It can be discussed what the exact lowest disease causing dose is, thus what the lower limit is for a person to qualify for treatment (Watson 1994). For anthrax, the disease causing dose is mentioned in the literature to be 8000 spores (derived from animal studies (Glassman 1966), but anecdotal cases have been known to have contracted pneumonic anthrax after being exposed to much lower doses (Glassman 1966, Brachman 2002). This complicates the decision of who should qualify for treatment in two ways. Firstly, the balance of avoiding casualties, and too many adverse effects from medication. Secondly, the cut-off limit could be defined by the stock of medication available e.g. prioritizing the people who have been exposed to the highest concentrations followed by the not-so-exposed and so on until stockpiles are used up. Looking at the output from a dispersion calculation (see for example front cover), this corresponds with choosing an iso-dose contour as the cut-off. The question is, should only people inside the red (inner) contour qualify for treatment, or should people in the yellow (outer) be included? What about persons outside, but close to the plume, who theoretically have received a small amount of agent, but below the chosen dose-limit? The choice will then become somewhat practical or political.

Not only does proximity to the incident define treatment requirements, persons with a higher risk of infection due to underlying diseases are also given high priority. This will typically be elderly, young children, immunodepressed persons, and persons with certain respiratory diseases (Webb 2002, Meselson 1994). To perform these analyses, the contour of the different exposure levels is exported into a GIS where attributional data on the exposed persons are brought together. Other high priority groups for prophylaxis are personnel important for response management: first responders, 2nd level responders, and decision makers.

4.2 Planning a mass medication campaign

Planning the dimension of a dispensing and medication centre during a prophylaxis campaign, the COMA unit uses a modelling tool[2] (Figure 4.1) to calculate the amount of resources that must be applied to service the expected number of exposed persons.

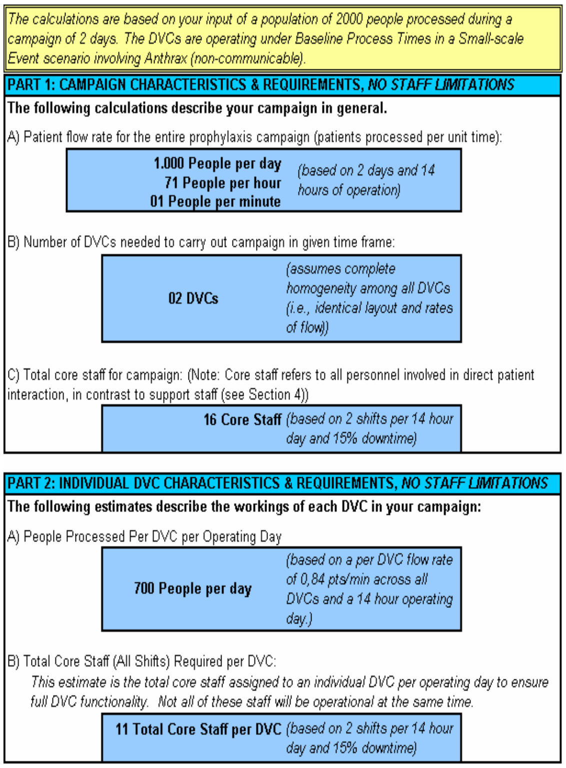

Figure 4.1 Excerpt from a modeling tool to determine staffing requirements during a mass prophylaxis campaign.
http://www.ahrq.gov/research/biomodel3/1.asp

[2]Weill/Cornell Mass Prophylaxis/Vaccination Model. By Nathaniel Hupert, et al. http://www.ahrq.gov/research/biomodel/howto.asp

Medication must be administered within a certain time frame to be effective, thus demanding quick resource implementation and high performance. The number of security personnel, station managers, data entry personnel, medical staff, re-supply staff, as well as equipment and medical supplies are calculated and recommendations are disseminated to the incident managing authority.

4.3 Expected number of patients demanding health care

A fraction of the exposed persons will fall ill and thus draw on hospital resources. Estimation of the total number of people expected to seek hospital treatment and daily admissions can be supported by use of modelling tools[3] [4]. The COMA unit provides the public health crisis management group with estimates, so that sufficient staff may be called in at hospitals, and if necessary, to rearrange treatment procedures and postpone non-acute daily activities. Medicine and utensils can be mobilized from stockpiles or ordered in due time.

4.4 Duration of epidemic

Agents that can cause secondary infections may cause several waves of disease outbreak if an epidemic is not contained during the first wave. Modelling tools are used to calculate the number of people falling ill, dying and recovering. Prediction of when the epidemic peaks and how many will fall ill at what times are modelled, allowing optimisation of resource allocation[3] [4].

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[3] For Influenza: FluAid and FluSurge. http://www.cdc.gov/flu/pandemic/flusurge_fluaid_qa.htm
For smallpox (only for training purposes) : www.uni-tuebingen.de
[4] For unspecified disease: www.biobered skab.dk.

4.5 Validation of dispersion calculation

As mathematical modelling of dispersion is based on many assumptions and approximations of parameters the actual area of contamination needs to be validated eventually. The Field Investigation Team initially planned the sampling strategy according to the first dispersion calculation, including the strategy of environmental sampling to qualify the calculated concentration estimates. The laboratory analysis returns information on the concentration of spores sampled at increasing distance from the source, and subsequently conclusions on the precision of the calculated dispersion can be made. As the dispersion calculations are made with worst case assumptions the real contaminated area is most likely to be smaller than the estimated.

5. Management of covert release

The first indication of a covert release (type II incident) will be the appearance of casualties some time after the release, depending on the incubation period of the disease in question. The only indication of the extent of the release and the likely future numbers of casualties will be the time-dependent geographic disposition of casualties in the hours and days prior to them developing symptoms. Covert releases, therefore, pose particular difficulties for response.
It is discussed in this chapter how the modelling tools described in this report may have some utility, at least in planning for such responses. However, specific tools will be required to be developed if they are to be useful during the operational response.

As for overt releases, following a deliberate covert release of a biological agent the numbers of potentially exposed individuals could be orders of magnitude higher than those that might be expected to become ill (without treatment). The extent of this discrepancy depends on the risk of infection (and possibly death) that might be considered to be acceptable in the underlying population compared to the uncertainties in determining that risk, alongside the potential risks associated with any treatment(s). For example, as an illustration only in figure 5.1 below and not necessarily assumed to be an acceptable risk, an $LD_{0.1}$ represents a 1 in a 1000 risk of becoming infected (and for anthrax probably dying) without treatment. To compound the problem, it is also unlikely to be able to distinguish those individuals that would become ill from those that have been merely potentially exposed. Consequently, all those who have been potentially exposed (at some agreed probability of becoming ill) will have to be found by some means (which will be particularly problematic for a covert release where the site or source is initially unknown) and treated as quickly and efficiently as possible. In the case of anthrax this should ideally be done extremely rapidly and before symptoms develop in exposed individuals.

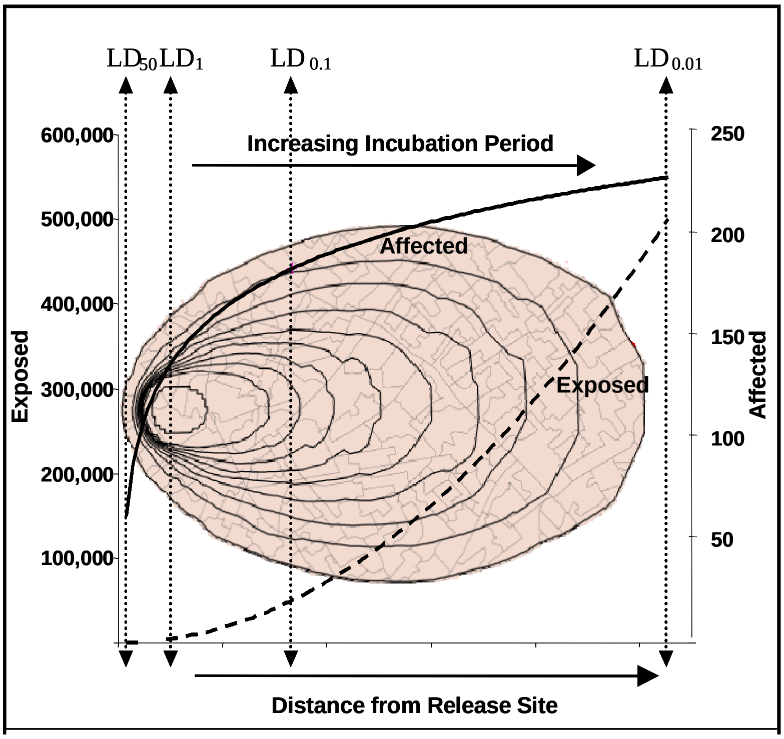

Figure 5.1 Results from a very hypothetical release, to demonstrate the possible relationship between distance from the point of the release and: the individual probability of infection and death without treatment for given dosages of pathogen potentially received (LD_n, vertical arrows, where n is the probability expressed as a percentage), the numbers of individuals exposed (dashed line) and the numbers affected (solid line).
Health Protection Agency

This is illustrated very simplistically in Figure 5.1 where the values given on the axes have had to be based on a single hypothetical scenario to provide an exemplar. Nevertheless, the approximate relationships that are being illustrated here are likely to remain true over a considerable range of similar scenarios (airborne release over open terrain). The probability of infection in those exposed (vertical LD arrows) decreases as their distance from the site of the release increases (x-axis). This is a function of the lower dosages of material that are likely to have been inhaled at greater distances from the release, in concert with the presumed dose response relationship to the pathogen. Thus, although the numbers of individuals potentially exposed are likely to increase very approximately as the square of the distance (dashed line) the numbers of individuals that will be likely to become ill without post-exposure prophylactic treatment will increase much more slowly and approach some limiting value with distance from the site of the release (solid line). These approximate relationships make a simplifying assumption that the population over which the plume of material has passed is evenly distributed, but this is reasonable for the purposes of the illustration here.

The public health-related challenges here are to identify the potential release site and the extent of dispersion (from the first and any ongoing casualties), estimate how far from the release site the risk of becoming infected might be acceptable (and to whom amongst the various stakeholder groups), and identify the potentially large numbers of individuals that might have been exposed at this level of risk and deliver treatment to them quickly.

Public health contingency planning requires the type of analysis described above to be integrated with other types of probabilistic individual-based risk assessment modelling in order to extend airborne dispersion models specifically for the public health context for a whole range of deliberate release scenarios. Important factors in such models are, for example, the likely incubation period distributions for individuals exposed to the pathogen and the extent to which this might vary depending on the dosage of pathogen received. For anthrax, incubation periods can, for example, range from hours to weeks depending on the individual and also inversely, but not linearly, on dosage. Models also need to incorporate aspects such as the time it is likely to take to find exposed individuals and deliver treatments to them. In the case of the types of scenarios considered here, which have been hypothetical deliberate releases over open terrain, quantitative risk assessments of this sort have demonstrated that it is feasible to find and successfully treat many of those who might otherwise have succumbed. This is even true for anthrax, despite its high mortality rate (without early "pre-emptive" treatment), rapid requirement for treatment, and relatively short incubation period, but particularly at high dosages.

This type of pre-planning analysis demonstrates that there are further public health challenges when it comes to “real-time” responses to covert releases. This is because it will be individuals seeking medical help that provide the first evidence that a release has taken place. The first to succumb to the release will, on average, probably be those that have been exposed to the highest dosages of the biological agent. From what has been said above, it is likely that these will be those that have been nearest to the site of the release. An important aspect for public health at this point will be to rapidly link the unusual epidemiology and presentation of these cases, recognise the development as a potential deliberate release, identify the biological agent, and conduct careful investigations to determine the geographic locations of affected individuals at times and dates leading up to the onset of the disease. From these it will be important to rapidly identify the site and extent of the initial release using developments in airborne dispersion modelling and related geo-spatial statistical modelling techniques, based on the geographic location of cases in relation to the likely incubation period distribution for the biological agent. Such modelling strategies still need to be fully developed but would have to be rapidly applied in order to find other probably exposed individuals that are yet likely to develop symptoms and administer treatment to them. Such individuals will have to be inferred from the modelling and the ongoing epidemiological studies but will be likely to be those which have received lower dosages than the initial cases at locations further from the site of the initial release.

Early detection of disease outbreaks after covert releases

Responding to a covert release (type II incidence) can only be initiated when the disease outbreak has actually been detected. This can be on the basis of a sudden increase in medical cases or on background of diagnosed exotic disease. Surveillance of systems that collect medical reports or the monitoring of proxies for disease outbreaks has been developed in many versions around the world (Brookmeyer 2001, Grandjean 1984, Bravata 2002, Das 2003, Eidson 2005, Grenco 2003, Lober 2003, Lombardi 2003, Mostashari 2003).

Classical epidemiological surveillance systems have been developed to have a high specificity. The consequence is that the detection of an outbreak will come late (for example after laboratory analysis days after the first case detected with symptoms).

Driven especially by bioterror threats and emergence of SARS and avian influenza, development has in recent years been aimed at timeliness. Monitoring syndromes of influenza like illnesses (representative for most bioterror related diseases) from automated databases greatly reduces the time for detection. Data that has been known to be used are: over-the-counter drug sales, school and work place absenteeism, sentinel systems of emergency room diagnoses and general practitioners, ambulance dispatch data, and other sources of data as well as entirely newly developed systems (Mostafari 2003b).

Tests made by the authors and colleagues show that the reporting of outbreaks from three known incidents: an outbreak of Toxic Oil Syndrome, anthrax release and influenza epidemic, was out-performed by a monitoring system based on ambulance dispatch data (Bork in press, Brookmeyer 2001, Grandjean 1984, EPI-News 2004).

6. Description of dispersion calculation systems and some implications

This chapter describes dispersion systems in general, what components they consist of, and the input of data needed. Furthermore, the user inter-face, dispersion results, their interpretation and validation will be discussed.
A number of available systems are described in chapter 6 as inspiration to incorporate decision support systems in response management during biological incidents.

6.1 The mathematical models, data and user interface

DISPERSION MODEL
Dispersion of biological material can be described in a mathematical model as a number of puffs of material being released over a period of time, widening in their distribution in space while it drifts with the wind (Figure 6.1). In combination

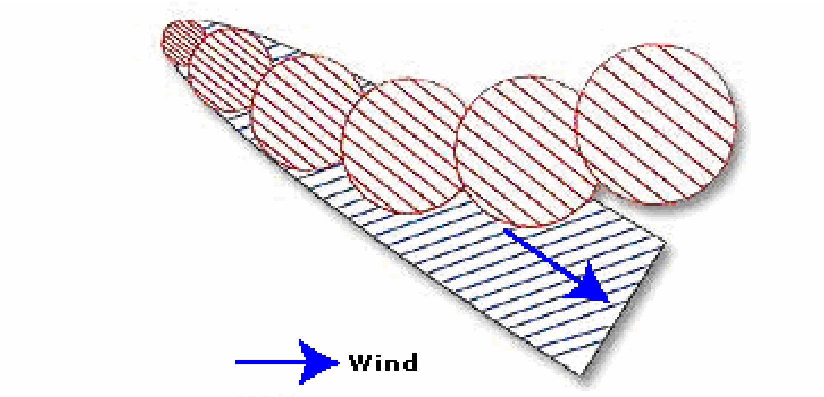

Figure 6.1 A spherical cloud of material puffs with a decreasing concentration towards the periphery, widening as they drift down-wind
Modified from http://www.scientificsoftwaregroup.com/pages/detailed_description.php?products_id=199

with information about the weather, landscape, topography, agent specific parameters, deposition velocity and degradation, the model is able to predict the area of contamination.
Mathematical dispersion models can be incorporated into systems with user-friendly interfaces with access to input data, producing dispersion results in due time to implement response measures.

The quality of the output is influenced by the degree of details in the underlying parameters; the resolution of the meteorological and topographical data, the detail of the landuse data, and also location and outline of buildings.

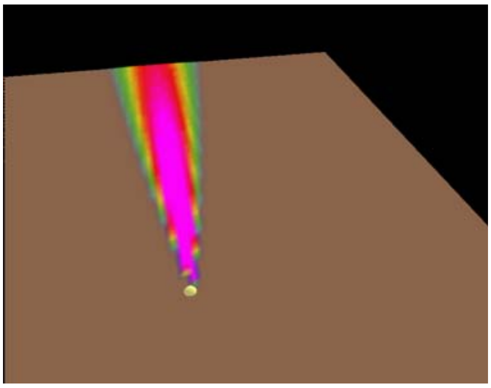

Figure 6.2 Dispersion calculation without use of data on topography resulting in a uniform contaminated area.
From: Urban Dispersion Model by Defence Science and Technology Laboratory, Porton Down, UK

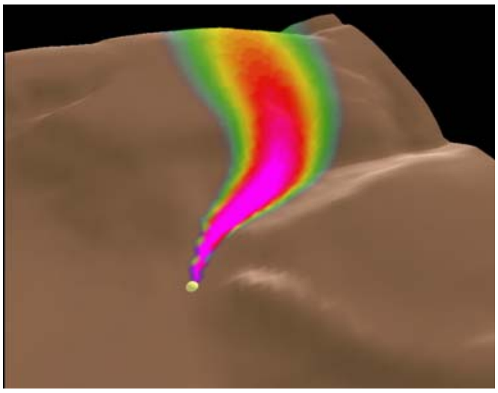

Figure 6.3 Dispersion calculation, incorporating data on topography, resulting in a somewhat relocated and broader contaminated area.
From: Urban Dispersion Model by Defence Science and Technology Laboratory, Porton Down, UK

For example, two calculations have been produced to illustrate differences due to topographical data input, All parameters were held constant, resulting in a somewhat diverted and broader plume, when including data on topography (Figure 6.3) compared to the calculation where no topographical data were included (Figure 6.2).

INCIDENT MODELS

For a system to function in a timely manner, a number of default incident models should be available beforehand to avoid spending valuable time on defining the physical characteristics of the initial release. Correct modelling of the plume close to the source has a very high impact on the further down-wind dispersion, which is why the correct choice of incident model is of great importance. Different types of incident models describe point release, line-release, release from aerosolizers, explosions and munitions. These models can be further refined by making pick-lists with known delivery systems as for example conventional weapons where the characteristics of, say, an eight kg bomb can be predefined very precisely because its specifications on explosion characteristics (heat release, momentum, container size etc.) are known in detail. An example of an improvised delivery system that could be modelled as a default incident type, could be, how an agent is released from a proto-type agricultural aerosolizer where specifications of nozzle diameter, flow rate and droplet size is incorporated. Such incident models, with very well defined delivery systems, will, when appropriate, generate more precise and reliable results than more generalised incident models.

URBAN DISPERSION MODEL

A likely bioterror scenario is an open air release in urban settings. The challenge to an urban dispersion model (UDM) is to model each puff, being held back by buildings, being dispersed above and around them, and channelled through urban canyons (streets), (Figure 6.4). (Hall 2001, Astrup 2005).

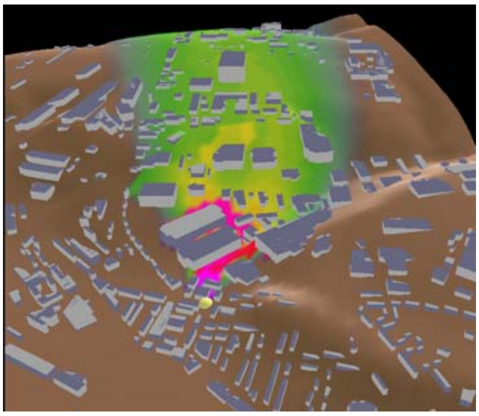

Figure 6.4 Urban dispersion using urban micro-meteorology and 3-D building data. (Note that the place of release is the same as figure 6.3)

From: Urban Dispersion Model by Defence Science and Technology Laboratory, Porton Down, UK

The meteorology in cities with high abundance of tall buildings is complex, and for the UDM, the resolution of the gridded weather files should be down to, preferably, 100 square meters.

In Europe, numerical weather prediction files are readily available in a resolution of 9-45 km grids and many countries are able to produce weather data in higher resolutions.
Development of UDMs is ongoing, and models have already been incorporated in some real-time systems. Most likely, lack of data on buildings and the technical integration of these, will be the hurdle for many potential users.

DEPOSITION AND RE-AEROSOLIZATION MODEL

Part of the material in a passing cloud will fall out and stick to surfaces and will not be part of the fraction of material hazardous to humans. Some of the deposited material can eventually be reaerosolized and again become available for inhalation (Resnick in Inglesby 2002). This generates the problem that potential infection from reaerosolized material will extend the period of cordon sanitaire and inflict problems of re-housing and probable closing of civil functions.
Existing decision support systems include deposition models but do not incorporate models for reaerosolization. Reaerosolization can occur days, months and possibly years afterwards. In an outbreak due to an accidental release of weaponized anthrax in Sverdlovsk in the former USSR, anthrax cases appeared up until six weeks later, exceeding the incubation period of 1-10 days. This implies that the latter cases could be due to reaerosolization or extended incubation time due to low dose exposure (Meselson 1994). Furthermore, tests following contamination of the Hart Senate Office Building in Washington DC after the 2001 anthrax letters have showed that some reaerosolization did occur (Inglesby 2002).

INACTIVATION MODEL

Biological agents have varying decay rates dependant on the environment: humidity, temperature and UV (sunlight). Therefore, a model must take into account that the concentration of live organisms is not only reduced due to dilution after the release (expansion of plume in large volumes of air), but also to a high extent due to degradation.

Information about the agents and their ability to survive is for some agents not very well known, and it must be expected that data for weaponized agents are not available, thus being a source of inaccuracy in dispersion calculation results and casualty estimates. Particularly, the aerobiological properties, durability and pathogenesis have been the subject of manipulation in the weaponization efforts. This includes techniques for coating in order to avoid agglutination and to protect the agent against degradation caused by UV, and also genetic manipulation to increase pathogenesis and resistance towards known therapeutics

WEATHER MODEL

The different types of dispersion models use different kinds of weather models which are beyond the scope of this report to describe, but some general remarks are required. Some dispersion models simply use constant wind velocity, direction and a stability class, while other dispersion models make use of complex numerical weather prediction models that model mean wind, turbulence, inter- and extrapolation in time and space from land and sonde observations, land surface characteristics, land heat flux and momentum fluxes (Grell 1995, Hogan 1991).

DISPERSION CALCULATION RESULTS, PRESENTATION AND INTERPRETATION

The output from a dispersion calculation should be presented as integrated inhalation doses because this is the essential unit in relation to human exposure and casualties.

The total number of casualties can be calculated from how many people are living in an affected area, or if the incident is during the day, how many people are working in the area. As a bioterror attack possibly could take place in a city where many people are moving from one location to another and are likely to pass through the cloud, only being exposed in part of the cloud passage, questions can arise regarding to what degree a person has been exposed. Presenting the dispersion results as integrated inhalation doses, it is possible to calculate how many doses have been inhaled from one time step to another.

The concentration estimates that can also be calculated as outputs can be used for validation when results from laboratory analysis of the environmental samples become available. Environmental samples systematically sampled from transects running down-wind, will produce results that will describe a concentration gradient. Comparison of predicted and observed concentrations can be used to validate the dispersion calculation, after which any implemented countermeasures can be evaluated and adjusted.

The integrated inhaled doses and concentrations should be presented as contours on a map for easy interpretation. The question of what outer concentration contours should be included (i.e. what is the lowest concentration of interest) is discussed in 4.1 with considerations of health perspectives and impact on society.

VALIDATION

For response managers, the quality of dispersion estimates must be known, and uncertainties must be taken into account when planning and implementing measures, as well as when passing recommendation on to other stakeholders. Evaluation studies have been performed for many models and systems: small-scale wind tunnel studies, medium scale studies, large scale releases, as well as measurements from accidental releases from real incidents. Also, comparative studies of systems’ performance can be informative as to the degree models might predict differently.

Validation studies will be described for each of the models included in chapter 6.

DISPERSION IN BUILDINGS

Dispersion in buildings can be viewed as three sub-categories: dispersion entirely inside buildings, exfiltration from inside buildings to the exterior, and agents filtering into buildings.

Modelling indoor dispersion is complicated by the description of flow between rooms and through ventilation systems which are unique for all buildings. Dispersion models and parameterisation of the interior layout can be used to model in-door dispersion and a catalogue of such “standard” buildings could serve as dispersal assessment. Buildings are of such diversity that this is not a useful way forward, and the in-door dispersion issue has to be considered unsolved. Decisions can be supported by gross results from historical cases of cross contamination of, for example, smallpox inside health facilities (Ström 1966), and dispersion assessments from the Brentwood postal facility after the 2001 anthrax letters (Kournikakis 2001, Lustig 2001, Web 2002).
Exfiltration models have been developed but together with the problem of modelling in-door dispersion, are the challenges of modelling exfiltration from buildings with outer wall constructions of different kinds and materials, as well as modelling problems with ventilation installations.
Studies of agent filtering into a building have been made, (Levin 2003, Teschke 2001) and results can support decisions concerning evacuation. Tescke and his colleagues found that in-door concentration following open air release of *Bacillus thuringiensis* exceeded out-door concentration after 4-5 hours (Figure 6.5). This implies that recommendations of personal protection should be to stay in doors only during the first hours of an attack, and subsequently leave the building and/or air out.

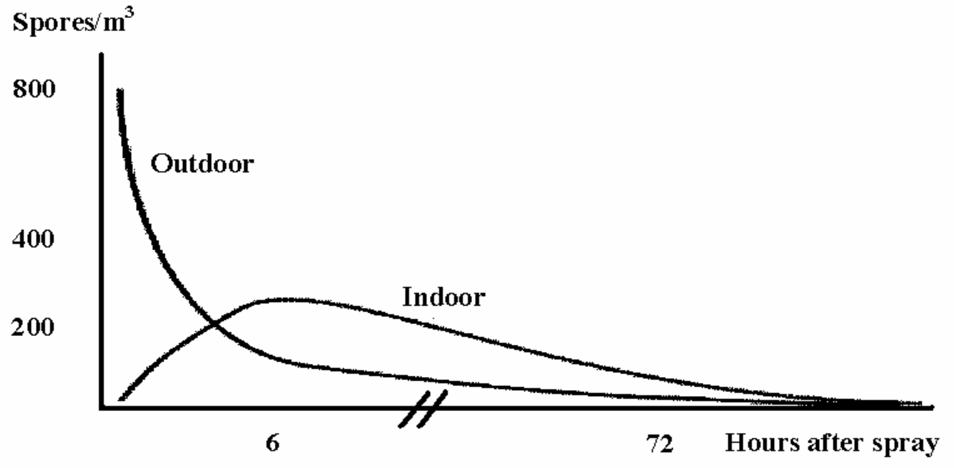

Figure 6.5 The concentration of spores filter into buildings increasing the indoor concentration the first 6-7 hours, whereafter the concentration slowly decrease. The outdoor concentration falls below the indoor concentration after four hours.
Based on data from Levin 2003

6.2 Data

GEOGRAPHICAL DATA

Geographical data are used in the dispersion model for the actual calculations and subsequently for visualisation. A meandering landscape and landuse divert and hold back the plume. For example, cultivated land has a higher roughness value than water and will to a greater extent "hold" back the lower part of the cloud. Figure 6.6 is a result from a dispersion calculation where anthrax has been sprayed from a plane over both water and land.

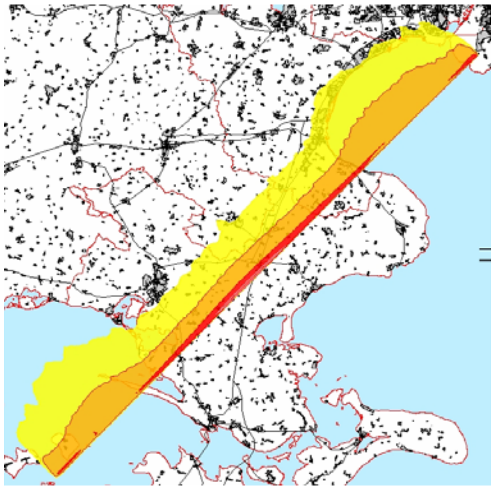

Figure 6.6 Anthrax travels further over water bodies compared to over land. Red contour indicates high consentration decreasing towards yellow.
HPAC run.

Agent released over water travels further, covering a large area with a lower concentration while the part released over land is somewhat held back, resulting in a smaller contaminated area, but with higher concentrations.

To run the UDM mentioned previously there are requirements to geographical data concerning buildings. Because the UDM models cloud-transport around and over buildings, the buildings must be described in detail with actual position, base outline, and height.

To use the dispersion calculation output for real time decision support the results should be presented graphically on a map, ideally including streets, street names, buildings, and other features in order for responders and incident commanders to gain easier orientation in the area.

The dispersion calculation output should be in a format that can be exported to a digital geocoded map and used in a GIS to perform analysis of additional data, such as proximity to buildings of special interest, health status of the exposed, or other available area-specific data.

DEMOGRAPHICAL DATA

Data on demography are used to estimate human response, and are also used in the following calculation of PAR.

Some countermeasures are based on demographical data. To improve the casualty estimate, data on parameters that lower the dose response, such as data on age and underlying disease burden, can be included. Data for day- and night population should be known because there is a large part of the population that changes location during the day.

Data on high densities of people, in for example schools and large work places are important information for both PAR estimates and evacuation purposes.

Identification of individuals through the GIS with demographic data will be helpful for contacting persons that are to receive treatment.

WEATHER DATA

Data of high resolution and reliable forecasts are essential in a dispersion calculation programme. The relatively limited scale of some bioterror scenarios requires that data on weather are of a higher resolution than what is known for nuclear scenarios. The currently available data from international weather servers are of a compromise resolution (not the ideal intrapolated data of down to 100 meters). High resolution data are in some cases available from national weather agencies and are of higher quality than what is available from international weather servers, though the format is not necessarily compatible with the airborne dispersion systems and could require extensive adaptation efforts.

BIOLOGICAL AGENT DATABASE

Parameters of agents are used in the dispersion models and the human response model. These parameters are aerobiological properties (size, weight, structure) and pathogenesis. Also data on the agent’s stability when exposed to heat, UV, humidity, and mechanical stress from a dispersion device (explosive or spraying device).

SYSTEM IMPLEMENTATION AND USE

The performance of the system must be designed to correspond with the standard operational procedures of biological incident management, characterized by iterative and timely calculations. Not all information for a definitive dispersion calculation is available in the early stages of an incident. The calculations must be made again and again as new upgraded information becomes available, each time qualifying the dispersion estimate. The system should be supplied with default values for submodels and relevant parameters such as agent, release type (weapon/device), and have automated down-load capability for meteorological-, topographical- and demographical files.

Manipulation of output should be easy accessible for different visualisations: area of exposure, time of arrival of the plume, peak concentration, time dependant inhalation doses, deposited material and other relevant visualisations. The system should have some map handling tools, including zoom properties, overlay features, measuring tools etc.

7. Available Systems

There are a number of decision support tools in use in different countries and institutions that can predict dispersion and effect of hazardous material. Decision support systems in this chapter are neither a prioritized nor a complete list, but merely describe four systems that are in use and, to different degrees, fulfil needs described in the previous chapters. The systems are analysed through literature studies and have not been validated or extensively compared under the MODELREL project. There is a discrepancy between the richness of details in the description of the four systems that reflects the resources spent on the particular systems by the authors. This does not reflect the quality of the systems described.

7.1 NARAC

The National Atmospheric Release Advisory Center, NARAC, provides tools and services that calculate the probable spread of hazardous material accidentally or intentionally released into the atmosphere. NARAC provides dispersion predictions in time for an emergency manager to decide if taking protective action is necessary to protect the health and safety of people in affected areas.
NARAC uses the newest dispersion prediction capabilities during real time incidents; modelling concentrations, integrated inhalation doses and human response.
NARAC offers two independent applications, NARAC WEB and NARAC iClient.
With NARAC WEB it is possible to enter relevant data into a questionnaire and send it online to NARAC who will return a dispersion calculation with information, including map images and casualty estimates after 5-15 minutes.

This solution enables response managers to receive support from dispersion calculations without having dispersion capabilities in-house.
NARAC iClient is a stand-alone solution where an end user system is installed locally, enabling local accident managers to perform dispersion calculations and casualty estimates in-house. (Sugiyama 2004a, 2004b).

DISPERSION MODEL

The puff based dispersion model uses a Lagrangian stochastic, Monte Carlo method, LODI, which includes methods for simulating the processes of mean wind advection, turbulent diffusion, bio-agent degradation, dry and wet deposition, and precipitation scavenging. For fast initial dispersion it uses a plume model with minimal input (constant wind). (Nasstrom 2002, Ermak 2000).
Variable source terms are modelled: point, line, area, multiple, moving, time-varying, momentum and buoyancy plume rise as well as explosions and spraying devices. (Nasstrom 2005).

OUTPUT/CALCULATION RESULTS

Cloud passage is georeferenced ready to be loaded into GIS applications. Output options are air concentration, time-integrated air concentration and doses, ground deposition, integrated ground exposure, time series of exposure and in-contour population. Results are visualized on an integrated map (Figure 7.1).

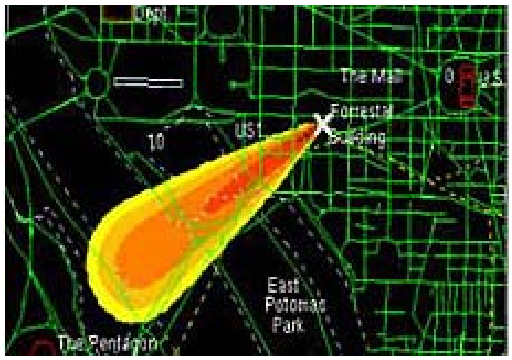

Figure 7.1 Illustration of output from NARAC's local scale moddel. Contours with varying contrations.
Narac: http://narac.llnl.gov/modeling.php

Summary reports, containing health risks, suggested emergency actions and sumary of the release, are available. Measurements of concentrations can be entered, and displayed on the map.

The system is supplied with extensive map handling features and can display maps of different origin.

WEATHER MODEL AND DATA

The NARAC dispersion model processes gridded data from multiple meteorological data sources, including observations on mean winds, pressure, precipitation, temperature, and turbulence, using a variety of interpolation methods for observations from surface, tower, balloon, and stations (Sugiyama 1997). The forecast models are global and regional data from NOAA, Navy or COAMPS regional model (Sugiyama 2004a, Hodur 1997). Global weather data are accessed through meteorological servers.

URBAN DISPERSION MODEL (UDM)

NARAC's wind dispersion tool does not include an urban dispersion model, though recent work has been done to apply an UDM, developed by Defence Science Technologies Laboratory (Dstl) (Hall 2001) and should function for some locations, where sufficient 3-D data on buildings exists. Model testing on field trial data are ongoing and preliminary background results are available (Brook 2002).

GEOGRAPHICAL DATA

For visualisation, results are presented on maps of different origin: VMAP and ADRG maps allowing overlay for any location in the world importable in common GIS products. The GIS adaption enables most countries to use local map projections, and import dispersion calculation results.

The data used in the dispersion calculations are of varying resolution, depending on data availability. The system can work with a resolution of elevation down to a 30 metre grid and for landuse 1 km grids.

DEMOGRAPHY

Population data are taken from the LandScan database from Oak Ridge National Laboratory[5] which is a worldwide population data base based on best available census counts, or estimates based on road proximity, slope, land cover, and nighttime lights. Data are allocated to grided cells at 30"x 30" resolution (approximately 1 km squares). This relatively low resolution is not sufficiently detailed for the nature of smaller incidents and will be likely to only include few complete grid cells, with most other grid cells only partly affected because of the relatively large one square kilometer grid. Thus a large number of people will be potentially included that will not have been exposed should one include all affected cells to make sure all of the affected population is included. Large discripancies between LandScan and local census data have been found from an analysis on Danish population data (see box 2 in 7.3). This would lead to misinformation of response managers, and subsequently, malplaced and poorly dimentioned countermeasures.

BIOLOGICAL AGENT DATABASE

The models are coupled to the NARAC databases providing, chemical-biological-nuclear agent properties and health risk levels. Detailed description of the NARAC bio database has not been obtained by the authors.

ADDITIONAL SERVICES

NARAC services include support staff that assist users on a 24/7 basis to provide scientific and technical assistance before, during and after incidents, and there is an on-line help service. NARAC offer evaluation of the dispersing predictions post-incident and for some agents near real-time. Also, training and help for implementation of the system is supplied. NARAC can give recommendations of protective actions.

[5] http://www.ornl.gov/sci/landscan/ Accessed July 2006.

USER INTERFACE

Information concerning the incident is entered into the system via menus: type of release (biological/chemical/radiologcal), time, location, scenario (point, line, explosion etc.), agent, amount etc. Importation of data is automated for various map formats, weather files, terrain, landuse, demography by single click on icons.

INTEROPERABILITY

NARAC runs on a normal PC under the Windows environment. The software can export plumes into a GIS enabling geospatial analysis. In the GIS, transport routes can be planned, information about the affected population can be analysed (i.e. health data, age, vehicles ownership etc.), as can places of special interest (government buildings, schools, hospitals etc.) and other georefferenced information that may be available.

The NARAC system can export images of dispersion results in the commonly used bitmap, jpeg and PDF formats.

MODELS TESTING AND EVALUATION

The NARAC wind dispersion system has been tested by analytic cases, tracer field experiments (Nasstrom 1998, 1999) and on data obtained after real incidents (Pobanz 1999). NARAC respond to several incidents every year: fires, accidental chemical releases and air pollution.

Validation analysis on Dstl’s UDM has been performed from field data sets (Brook 2002). Project Prairie Grass: Flat terrain; Savannah River Mesoscale Atmospheric Tracer Studies: rolling, tree-covered terrain; Diablo Canyon Tracer Study: Hilly, coastal terrain; European Tracer Experiment (ETEX): Continental Europe, URBAN: building, urban, regional. From the URBAN 2003 field experiments Dstl’s UDM shows results of correspondence with measurements using sulphur hexafluoride as a tracer gas (Neuman 2006).

AVAILABILITY

NARAC will consider granting access to software and services after validation of applicant. Guidelines are set when approached.

For contact:

National Atmospheric Release Advisory Center
Lawrence Livermore National Laboratory
P.O. Box 808, L-103
Livermore, CA 94551, USA
Fax: 925-423-4527
naracwebrequest@llnl.gov
http://narac.llnl.gov/

CONCLUSION

It is a strength that NARAC include many important models for initial puff releases (source term) because this is a critical modelling parameter in the dispersion calculation.

NARAC is in the process of incorporate an UDM, thus being competitive to other state of the art models and systems. NARAC is an attractive solution for countries without dispersion calculation capabilities because of the services, together with the extensive 24/7 support available from support personnel.

Output is displayed visually and map images can be exported in common formats, enabling easy and fast distribution to all stakeholders.

NARAC's modelling system has been applied and tested operationally during many industrial accidents and through field experiments, validating both dispersion model and operationality.

NARAC’s iClient can be operated by responders in real-time.

NARAC fulfils requirements as a decision support tool for biological incidents in real time.

7.2 ARGOS

The ARGOS system (Accident Reporting and Guidance Operational System) was initially developed to model nuclear dispersion and in the years after the Chernobyl accident in 1986, the development of both model and user system has been intensified. The system is currently used for nuclear emergency management in Poland, Estonia, Latvia, Lithuania, Ireland, Norway, Canada, Sweden and Denmark. A number of incident models describing initial puff release, and a number of materials have been added including chemicals, but no biological data base is incorporated in the system. The system can model particles with similar aerobiological properties, as for example an anthrax spore, and the system can calculate time integrated inhalation doses. No human response data are included for biological agents, though animal response algorithms have been developed for animal diseases, making it theoretically straight forward to implement a bio-human response model (Mikkelsen 2003). An adaption for biological scenarios has been developed for real time response for veterinary purposes, modelling foot-and-mouth disease (FMD) virus and includes dose response algoritms (Sørensen 2000, Sørensen 2006).
The system can be run on a PC locally and is dependant on the internet only for download of weather files.
Despite the missing bio database, current developments and the high level of activity in the consortium behind the ARGOS system warrant the system's inclusion in this report.

DISPERSION MODEL
The mesoscale dispersion model in ARGOS is RIMPUFF (Risø Mesoscale Puff model) (Thykier-Nielsen 1999), which uses a Langrian stochastic method that simulates puff and plume dispersion in real-time, integrating numerical weather forecast data or meteorological measurements from ground stations. RIMPUFF

incorporates data on different terrain types (landuse) and topographical data to model wind flows in complex terrain.

RIMPUFF is furthermore, equipped with models for different incident types. These source terms include time dependant releases, line release, stack and buoyancy releases, and explosions (Sorokovikova 1999 in Slørdal 2002). Source terms have been made into pre-specified incident types. There are no predetermined models for spraying devices or munitions.

Dry and wet deposition is modelled and includes information on deposition velocity of the material, wind stability, precipitation intensity, boundary layer height, surface heat flux, surface momentum flux, land cover, surface roughness, and wind speed (Thykier-Nielsen 1999).

The system is provided with a model for puff splitting when they grow to a specified size. (Hoe 1997).

OUTPUT/CALCULATION RESULTS

Different output can be presented on an interactive map as zones of levels of contamination, including: time-intergrated concentrations and inhaled doses, time-integrated ground concentration, and deposition concentration (Figure 7.2). Human effects can be calculated from the time-intergrated inhaled doses, but without the bio database this must be done seperately, which does not supply the user with results in real-time.

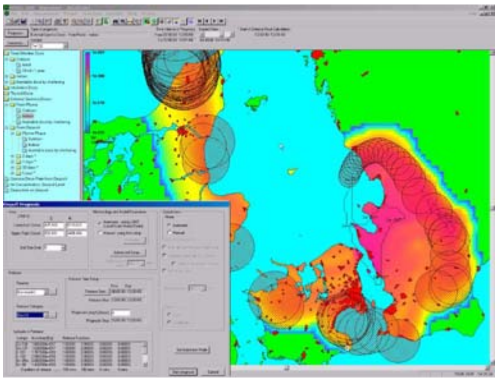

Figure 7.2 Visual presentation of dispersion results and on-screen reports. *ARGOS. www.pdc.dk/uk/cbrn/information/argos/*

Dose response cannot be presented for biological agents, but because the system works with integrated inhaled doses, it can readily be applied for biological agents, should a suitable database be made available. (Hoe 2002).

A veterinary on-line application (VetMet) has been developed for foot-and-mouth disease interspread among populations of pigs, cattle and cheep with dose response for foot-and-mouth disease and “agent” (virus, bacteria or fungi) (Mikkelsen 2003, Gloster 2003). Results are presented on a map (Sørensen 2006).

WEATHER MODEL AND DATA

The RIMPUFF dispersion model can process gridded weather data from several European meteorological institutes. The Danish HIRLAM (HIgh Resolution Limited Area Model) weather model covers all of the EU countries on a 15 km resolution, and higher resolution data (5 km) are available for Holland, Ireland, Scandinavia, the Baltic States and other parts of northern Europe (Figure 7.3 - yellow square).

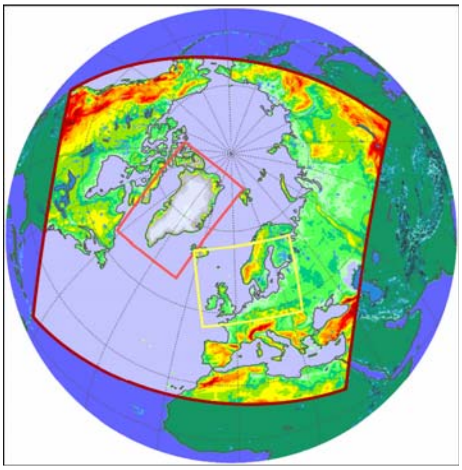

Figure 7.3 Areas of high resolution numerical weather forecasts. In the countries in the yellow square weather data is on a five km resolution.
Sørensen 2006

Weather data is updated every three to six hours depending on location and can be accessed via internet link. It includes information on mean wind speed, direction, pressure, precipitation, temperature, stability and turbulence. Uncertainties due to weather turbulence are calculated and included in the dispersion results.

URBAN DISPERSION MODEL (UDM)

An urban dispersion model is under developedment and is to be integrated in the ARGOS. The model is termed URD (Urban Release and Dispersion) and models building/puff-interaction near the point of release. (Astrup 2005).

GEOGRAPHICAL DATA

Gridded data on topography and landuse are used in the RIMPUFF dispersion model to model near-surface interaction. The member countries in the consortium use data sets of different origin with varying resolution. As an example, the model runs with a 5 meter resolution in Denmark. For use in the system, landuse data are divided into 21 categories: urban area, ocean, mixed forest, crops etc.

Maps are used for presentation of dispersion results, enabling responders to orient in relation to buildings, roads, and street names. There is also an import facility for commonly used GIS products ("shape" files and "geotif").

Due to the long list of countries in the ARGOS consortium a variety of national projection standards are compatible with the system and alternative projections can be integrated.

DEMOGRAPHY

For Denmark, correct positioning (+/- 5 metres) of people's home address and workplace enables a very precise PAR calculation with the possibility to identify individuals. For legal and practical reasons, gridded accumulated cells of 100x100 metres are used. Other Member States in the consortium use their respective national census data of varying standards and formats.

BIOLOGICAL AGENT DATABASE

There is no bio-database in ARGOS but dispersion of a "particle" with similar aerobiotic properties as a generalized bio-agent is modelled. The result is a realistic dispersion calculation, though degradation due to UV radiation, temperature and humidity is not modelled. There is no data on human response wherefore no casualty estimates are available. Implementation of a biological database can readily be incorporated due to ARGOS's modular construction but the database itself must be developed.

ADDITIONAL SERVICES

For consortium members meetings are held regularly and training sessions arranged on an ad hoc basis. Some members are engaged in developing projects with close scientific collaboration. System operators are on call 24/7 for incident response. All members have the opportunity to influence the development of models and facilities.

USER INTERFACE

The graphical user interface allows fast and logical operation of incident definition and input parameters. Operational editors and wizards give easy access to edit and define default values. Map handling and overlays are done in the system itself.

INTEROPERABILITY

ARGOS is implemented as a graphical Microsoft Windows NT™ application, to be used on standard PC’s.

Results from ARGOS can be exported in Shape- and Geotiff –files and results can be uploaded to the NARAC International Data exchange Platform.

MODEL TESTING AND EVALUATION

During the past 20 years, evaluation of the dispersion code (RIMPUFF) has been done on several occasions with SF6 (sulphur hexafluoride) tracer gas, and evaluation of real incidents (Sørensen 2000, 2003, Lauritzen 2003, Rojas-Palme, Thykier-Nielsen 2002).

The system was used real time during the FMD disease outbreak in England, 2001,to investigate sources of contamination (Sørensen 2003). Subsequently, dispersion results were compared to positions of sources and exposed animal stocks showing that the RIMPUFF model at least in some instances were able to predict the spread of virus. (Gloster 2003, Sørensen 2000).

The validation efforts on the basis of data from the spread of FMD in former GDR in 1982 and in Brittany 1981 showed that RIMPUFF explained, to a high degree contamination area and virus load (Sørensen 2000).
Comparison of the RIMPUFF code and the UDM, from Dstl reveals significant discrepancies in the near surface range wherefrom it is concluded that RIMPUFF should be supplemented with an UDM for near release modelling in urban areas (Astrup 2005).
The dispersion model was tested by the use of data obtained during the MADONA experiment where measurements from release of smoke, sulphur hexafluoride (SF_6), and propylene were obtained. (Cionco 1999).
Large scale testing has been performed with the 1990 Guardo trials (Thykier-Nielsen 1993).
Evaluation of the Chernobyl release on short scale dispersion showed: "quite good results and with a high level of detail when compared to the maps in the Chernobyl atlas"[6] (Brandt 2002).

AVAILABILITY

Future users can join the consortium behind the development of ARGOS whereby they get access to use the system as well as the possibility to participate in the further development. The fee is dependant on the respective country's BNP and is in the range of € 1.000, - to 10.000, - per year.
New users will be granted permission to use all modules but some will require extra payment or special warrant to secure misuse of potential dual use software.

For contact regarding the ARGOS consortia:
Danish Emergency Management Agency
Datavej 16
DK - 3460 Birkerød

[6] Chernobyl Atlas is a collection of concentration measurements of deposited material. (De Cord et al. in Brandt 2002)

Phone (+45) 45 90 60 00
Fax (+45) 45 90 60 60
Att: Steen Cort Hoe;
hoe@beredskabsstyrelsen.dk

For contact behind the veterinarian adaptation:

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Fax: +45 4677 5970
Att.: Torben Mikkelsen
torben.mikkelsen@risoe.dk

CONCLUSION

ARGOS has a strong future potential as a platform for a common European and Scandinavian biological emergency management system. It works with a state of the art dispersion model and European data bases. Because the system is build up of modules, it possible within a European environment to add new features and models.

For the system to be used as a decision support tool, a human response model will have to be developed, the URD needs to be integrated, and a bio database added. The system, as it is now, can make dispersion calculations in a timely fashion but cannot answer questions on casualties.

Ongoing development within the ARGOS Consortium should be followed closely as prospects are to have a tool for biological scenarios and an URD ready by 2008.

7.3 HPAC

HPAC (Hazard Prediction and Assessment Capability), developed by DTRA (Defence Threat Reduction Agency) provides the means to predict the effects of wind dispersion, and the impact on a population. It models nuclear, biological, chemical, and radiological types of incidents in different release scenarios, including explosives, munitions, production facilities, storage facilities and improvised dispersion devices. Output can be viewed as integrated concentration doses and derived products such as inhalation doses and human response.
HPAC runs on a standard lap top PC and useful output with initial setting can be obtained after 5-10 minutes. More valid calculations with downloaded numerical weather prediction files from external sources and production of easily readable visualizations on customized maps can be produced within an hour.

DISPERSION MODEL

HPAC's SCIPUFF (Second-Order Closure Integrated Puff) dispersion model is a Lagrangian model and uses a collection of Gaussian puffs to predict the average concentration and integrated inhalation doses. SCIPUFF employs a splitting algorithm, which divides puffs into smaller puffs as they grow larger during downwind transport.
The local topography and landuse are incorporated into the model using data on the landscape and a roughness category which determines to what degree the lower part of the cloud is held back. There are six categories of surface-roughness in HPAC: water, forest, cultivated, grassland, urban canopy and dessert.
HPAC provides a number of source terms, including instantaneous, continuous, explosive, liquid pool evaporation, stack and moving release. These are integrated in a number of default specified delivery devices (bombs, missiles, spraying devices and more), as well as default release scenarios, such as leakage from conventional containers and explosions in production facilities. The default delivery devices are activated by drag-and-drop menus.

The model solves gravitational settling, dry deposition, precipitation scavenging, simple deposition and liquid deposition.
An indoor dispersion model and an exfiltration model (material leaking to the exterior from a building) has been developed and implemented, still undergoing validation testing. (DTRA 2005).

OUTPUT/CALCULATION RESULTS

HPAC plots hazard contours as either integrated dosage or concentration values and as text labels listing human effects (casualties and PAR) (Figure 7.4).
Derived presentations are surface deposition, surface dosage, concentration, and human effects. Human effects are given as probability of infection and probability of mortality.

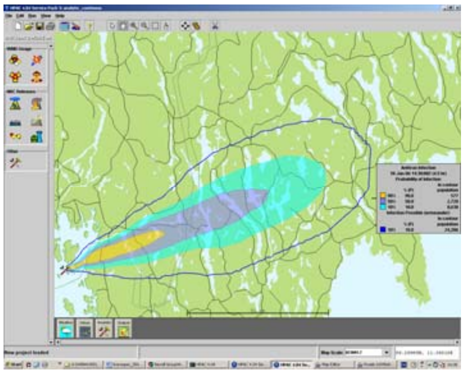

Figure 7.4 User interface and dispersion calculation from HPAC.
HPAC. DTRA

Probability of uncertainty due to inaccuracies in weather prediction files are available as plots (Outer blue line on figure 7.4).
Output is displayed as contours with predefined or customized iso-dose contours.
A user-friendly map handling tool is provided for simpler map handling functions: zooming, measuring tools, and display of varying map features.

WEATHER MODEL AND DATA

Meteorological data consist of gridded interpolated surface observations and remote sensing of mean winds, precipitation, temperature, pressure, turbulence and other parameters relevant for air borne material dispersion. A number of numerical weather prediction file formats can be intergrated into HPAC and are available from international weather servers. Import is fully automated, allowing real-time access to data for any location in world. The most relevant type for Europe is the MM5 (Mesoscale Model 5) (Grell 1995) that has a resolution of 9 and 27km, for Europe depending on location (CZ, UK, western NL, BE, north-west FR and the rest of the MS, respectively). In HPAC, further interpolation is done to correspond with the high-resolution scenarios of bio-incidents. The resolution of MM5 data is thought to be somewhat rough when used with an UDM, which models dispersion on a very fine scale.

URBAN DISPERSION MODEL (UDM)

In addition to the SCIPUFF model, HPAC includes an UDM together with a corresponding urban windfield module (UWM). In order to use UDM and UWM, HPAC requires a database of buildings with their accurate locations, planar geometries, and heights to support the calculation of flows in the urban setting. The UDM component of HPAC was created by the United Kingdom's Defense Science and Technology Laboratory (Dstl) (Hall 2001). The model construction of the UDM is based on wind tunnel studies, and in recent years a number of field trials have supplied data that have been used to evaluate the UDM performance with good results. (Warner 2004).

GEOGRAPHICAL DATA

The data on topography and landuse are used in the execution of the SCIPUFF model to model dispersion over complex terrain. Landuse data are obtained from the LandScan database, provided by the Oak Ridge National Laboratory for the entire world (URL[7]), and has a resolution of 130 arc degreeseconds, approximately 1 x 1km. This resolution is not optimal for small scale dispersion, though dispersion calculation results are still applicable.

Other geographical data are used for presentation, also originating from the LandScan database, including major roads, rail ways, rivers, administrative areas, populated places and others themes. Furthermore, maps of different format can be imported to improve the quality, which is highly relevant in that the LandScan map is not suitable for orientation.

[7] http://www.ornl.gov/sci/gist/projects/LandScan/landscan_doc.htm#Plume%20Intersections%20With%20Population. Accessed january 2007.

DEMOGRAPHY

Population data are taken from LandScan where population data is constructed on the best available census counts and/or estimates. The relatively low resolution is not sufficiently detailed for the nature of smaller bioterror scenarios. Large discrepancies between LandScan and local census data have been found from an analysis on Danish gridded census data (See Box 2). The difference is due to origin of data and to resolution. The LandScan data base has a resolution of 1 square kilometre whereas data from Denmark Statistics are given in 100 metre square grids.

Persons at Risk		Town of Fredensborg	
		Low Pop.	High Pop.
1g Anthrax	LS	**393**	**513**
1g Anthrax	SD	**1095**	**2386**
10g Anthrax	LS	**3433**	**3715**
10g Anthrax	DS	**2204**	**6131**

Box. 2. Calculated PAR based on LandScan (LS) as used in HPAC, and on census data from Statistics Denmark (SD). Four scenarios with two different amounts of released material, and at two different locations varying in population density were modelled. results show that estimated PAR vary. There is no trend in over- or under prediction. LandScan data are not desirable for short range dispersion.

Extensive work on population data, accessability and the building of a data warehouse has been done elsewhere under the MODELREL project[8] and could possibly help to support intergration of population data of higher resolution and quality.

BIOLOGICAL AGENT DATABASE

HPAC includes an extensive agent database. The biological data includes most agents that have been known to be weaponized: smallpox, anthrax, tularaemia etc., as well as bio toxins: botulinum toxin, ricin and others. Additional non-pathogenic biological agents used for experimental dispersion evaluation, such as *Bacillus thuringiensis* and a commonly used tracer gas SF6, are included for evaluation purposes. The data on each agent includes parameters that are relevant

[8] "A European Demographic and Population Movement Data Warehouse for Infectious Disease Modelling". Report and access to data warehouse can be made available on request from DG-SANCO, Directorate C - Public Health and Risk Assessment, Unit C3 "Health Threats".

for the ability to remain airborne i.e. size, weight and parameters relevant for pathogenesis and human response to the disease in question.

References to human response for biological agents are to the NATO Allied Medical Publication 8 and no references to aerobiotic parameters are given. It must be expected that parameters for weaponized agents will differ somewhat from the parameterization in the database.

HPAC includes chemical war agents such as blister gases, blood gases, and radiological particles as well as nuclear. A number of chemical agents for civil production purposes are in the database. The HPAC system also contains a wizard for editing and defining new agents.

ADDITIONAL SERVICES

As HPAC is used in NATO and at many military command posts around the world and by civil agencies[9], there are many training activities both at the DTRA in USA and in ambit of NATO, besides training sessions at the DTRA secure web site are tutorial, user guide and background material.

There is a 24/7 reach-back support for technical problems and an on-line help system is available.

USER INTERFACE

The graphical user interface (GUI) allows fast operation of incident definition and input parameters, and operational editors and wizards give easy access to edit and define default values. It also supports detailed export of results to other display environments; fixed map formats as well as digital geocoadable files for import into GIS tools.

INTEROPERABILITY

HPAC runs on a normal PC under the Windows environment.

[9] Bosnia conflict 1990s; 1996 Olympic Games, Atlanta; inauguration of President George Bush 2001; Studies of “the Gulf-War syndrome” Gulf War 1991 and 2002 Winter Olympic Games in Salt Lake City.

Graphically presented dispersion calculation results are exportable in the common ESRI Shape file format to be used in a GIS, and, reversely, shape files can be imported into HPAC.

HPAC can create Allied Technical Protocol 45 B (ATP-45 (B) messages; the current NATO standard.

Plume contours can be exported to other decision support tools such as CATS[10], NBC-ANALYSIS (chapter 7.4) and NBC-Crest[11]

MODEL TESTING AND EVALUATION

The performance of HPAC has been extensively validated through an ongoing testing program.

Studies of the performance of both the SCIPUFF and UDM, using data from a number of field trials has shown that the system is able to predict concentration fields, and area, with an acceptable accuracy (Allwine 2002, 2003, Brook 2002, Hanna 2003, Venkatram 2002, Cooke 2000, Batchvarova 2003 in Hanna). The many field trials have also resulted in creating a standard for “acceptance criteria” (Chang 2003).

Prediction ability of HPAC was tested against two other systems, where it was shown to have best performance for most release scenarios. (Chang 2005).

Interaction of the SCIPUFF model with weather models was tested to evaluate the influence of variation in meteorological data on SCIPUFF. The conclusion was that SCIPUFF in combination with meteorological data (field observations and NWM) could provide response managers with reliable support (Chang 2005).

Furthermore, some of the parameters in the weather data that could be a source of inaccuracy in the SCIPUFF prediction were identified and quantified. (Cox 1998).

---

[10] Consequences Assessment Tool Set. To predict damage and analyze consequences from natural and technological disasters. DTRA.

[11] Nuclear Biological Chemical Resource Estimation Support Tool. For Army medical planners to prepare for operations in NBC environment. Casualty and medical resources assessment. DTRA.

AVAILABILITY

To obtain HPAC, you must register and receive approval, which is made on a case-by-case basis. To register, please visit https://acecenter.cnttr.dtra.mil/acecenter.

The system and additional services are free of charge should access be granted.

Defence Threat Reduction Agency
Consequences Assessment Branch (SER)
8725 John J Kingman Road
MSC 6201
Ft. Belvoir, VA 22060-6201
Phone: (1) 703-767-3419
Fax: (1) 703-767-3387
acecenter@cnttr.dtra.mil

CONCLUSION

HPAC uses state of the art dispersion models and incorporates a number of relevant source term models, enabling users without modelling expertise to create realistic dispersion calculations. An extensive agent database is incorporated, including agents normally used for field experiment, making it possible to validate against these.

It has shown to be complicated to import building data from various standard file formats into HPAC's UDM. Import features must be developed before an UDM is practically available for EU Member States.

There is no reaerosolization model.

Through a number of validation studies, HPAC prediction capabilities have shown to produce reliable results.

Automatic incorporation of numerical weather prediction files makes the system run in a timely fashion.

The output contours are readily interpretable for responders and useable for further decision support.

Having a dispersion prediction system as a tool in a biological response institution is mandatory and HPAC fulfils the necessary requirements to a high degree.

7.4 NBC-ANALYSIS

NBC-ANALYSIS is a risk management tool to predict contaminated area, concentration fields, impact on military forces and installations, and to display, report and redirect military operation in due time. It predicts expected time of hazard arrival, and estimates when the hazard has passed. The dispersion prediction is based on so-called Allied Tactical Publication (ATP-45) -templates of circles and triangles, much like early NBC procedures, using paper maps and calques. It is based on low fidelity inputs and is expected to be operated by battlefield personnel. (ref.: ATP 45 (B)).

Input data can be entered manually and digitally: data on meteorology from weather servers, ad hoc deployed measuring stations and from automated sensors for chemicals and radioactivity.

The stand-alone system includes extensive mapping functions, message handling, and a communication module for immediate warning, and it displays military unit positions and key installations. Execution time, including entering and down-loading data, can be done within 5-30 minutes, depending on the level of information available.

DISPERSION MODEL

The dispersion calculation consist of pre-calculated templates, in most cases depending on the release scenario and agent, of simple geometrical shapes; circles, triangles or polygons (Figure 7.5). The user can enter parameters that are received through standardized messaging procedures in the NATO standard manually, or import weather information and sensor readings digitally should they be available. The system handles updates of continuously changed dispersion predictions and communicates these in a standardised manner.

A number of incident models are available for biological attacks: “air”, “sub surface” (bunkers), “surface”, “release other than attack” and “unknown”. Combining this with dispersion type: “aerial line spray”, “point” and “multiple

points”; a predetermined radius around the point of attack is assigned. The down wind extent of the hazard area is calculated from wind direction and speed, and incident type, defined by straight lines extending down wind where width of the resulting triangle is given by a product of wind speed and incident type (Figure 7.5). Should 4-D meteorological files be available, more precise and detailed hazard areas can be calculated, though still as simple geometrical forms. (ref.: AEP-45 (A)).
The model can calculate estimated time of arrival/passage of a cloud, from information of wind speed and terrain (surface roughness).

OUTPUT/CALCULATION RESULTS

Output is presented as a polygon on an underlying map as seen on figure 7.5. The polygon can be animated in time steps from which conclusions can be deduced as to what time a cloud of hazardous material will arrive into a zone.
Military units and places of special interest can be displayed and the system produces communication logs that can be shown on the screen.

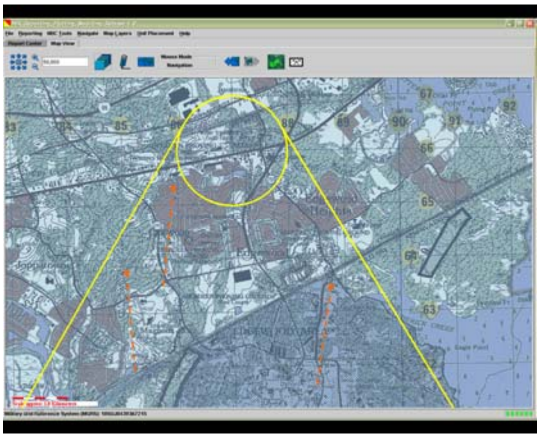

Figure 7.5 Screen dump from NBC-Analysis, showing hazard area, consisting of circle around point of attack and extending template.
Bruhn NewTech. Fact sheet.

WEATHER MODEL AND DATA

NBC-ANALYSIS does not make use of gridded numerical weather prediction (NWP) directly but predictions of speed, direction and other weather parameters derived from NWPs can be used. Download of field measurements from weather stations can be done automatically or wind direction and speed can be entered manually. Data originate from existing weather stations or ad hoc weather stations from deployed forces.

The meteorological data used for hazard prediction can be displayed on the map as wind barbs.

URBAN DISPERSION MODEL (UDM)

None

GEOGRAPHICAL DATA

The data that go into the dispersion calculations are constants describing the type of landuse: forest, urban, water etc. (ref.: AEP 45).

The user interface is supplied with extensive map handling tools. Besides the usual tools for zooming, panning and measuring; military forces can be displayed during their movements and reports on number of troops, available equipment and resources can be called. (ref.: fact sheet).

Multiple map formats (ASPR, ADRG, CADRG, VPF, CRP) and coordinate systems are supported: Universal Transverse Mercator (UTM, WGS84), Military Grid Reference System (MGRS), British/Irish National Grid (BNG/ING) and Latitude/Longitude (degrees, minutes and seconds). Way points can be inserted and a drawing and writing tool is available. (ref.: fact sheet).

DEMOGRAPHY

There is no population information included in the system and export to standard GIS tools to bring hazard area and underlying population together is not supported.

BIOLOGICAL AGENT DATABASE

The agent data base consists of six generalised classes of biological agents: bacteria, virus, rickettsiae, toxin, chlamydia, unknown; each contributing with unique parameters that influence the extent of dispersion. (ref.: AEP 45).

No data on human response is available.

ADDITIONAL SERVICES

Tuition is offered in 90% of NATO countries and advanced courses are held at the NATO school in Oberammergau, Germany.

USER INTERFACE

The user interface is extensively developed, making it possible for non-specialists to enter data in dialog boxes and to use pick-lists. Furthermore, results are easily displayed, manipulated and dropdown reports are available by single mouse-clicks.

INTEROPERABILITY

NBC-ANALYSIS runs on a normal PC under the Windows environment. In addition, integrated versions of NBC-ANALYSIS support UNIX and LINUX.
NBC-ANALYSIS is in compliance with NATO STANAG 2103 (ATP-45(B)) ref.: AEP-45) and NBC messages are generated with the message formatting rules contained in the NATO publication ADatP-3, USMTF & JVMF.
HPAC plume contours can be imported, allowing for the use of advanced dispersion calculations in response management and to make use of NBC-ANALYSIS' advanced and standardised messaging features.

MODEL TESTING AND EVALUATION

NBC-ANALYSIS has been tested against HPAC by James Heagy (2004) and it is concluded that NBC-ANALYSIS often makes false positive predictions (too large hazard areas), and in some cases, false negative results, mostly due to unrecognised meteorological uncertainties that NBC-ANALYSIS does not recognise, due to the low fidelity weather data input.

AVAILABILITY

NBC-ANALYSIS is available as a commercial off the shelf product, which can be used by military and civil emergency authorities.

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CONCLUSION

Compared to the above described LODI-, RIMPUFF- and SCIPUFF- models, the ATP-45 templates technology is not up to date, and the ATP-45 templates over-predict the size of the hazard area (Heagy 2004, Demyanovich 2002), leading to unnecessary extensive countermeasures and use of resources.

NBC-ANALYSIS has unique capabilities to communicate in NATO standard messaging formats and it can import HPAC's high quality dispersion modelling results.

The system does not include population data, or the ability to calculate integrated inhalation doses, thus no information on civilian casualties can be obtained.

Without having the ability to produce a reliable PAR estimate, and because of exaggerated hazard areas, the system is not applicable for civilian bioterror incidents.

8. Discussion

Incident response involving biological agents is complex. Even if a release is overt, the agent will remain unidentified for some time until samples have been analysed in a laboratory. Despite this, many critical decisions have to be made in the early stages to mitigate the potential consequences, and therefore any countermeasures may have to be adjusted as the incident evolves. Information about how the agent has been dispersed, the physical structure of the immediate environment, the topography and weather data; are input to the dispersion calculation system that are likely to be changed as more information – including intelligence - becomes available.

A field investigation team (FIT) can supply the dispersion calculation experts with critical information that is not initially available. Well qualified FIT members will be able to deduce conclusions from the release location that could lead to a specification of the agent, resulting in more correct dispersion estimates; information that would normally be available many hours later after laboratory analysis. The FIT should preferably be persons with a medical or bio-technical background, to be able to improvise sampling techniques and to sample in a complex setting (improvised laboratories, stockpile facilities, damaged installations).

Improvised dispersal devices, rather than solely military munitions, are relevant when considering bioterror carried out by terrorist groups. Formerly, biological weapons were reserved for national weapons programmes for battlefield deployment and to be delivered by military delivery systems. Improvised dispersal devices demand an extended knowledge of technical equipment such as laboratory and production equipment. Knowledge of laboratory techniques amongst FIT members, and being able to understand scientific literature, sketches and manuals, possibly present at the release site or laboratory, might allow a presumptive identification of the agent.

FIT personnel should additionally have an understanding of forensics to be able to sample and navigate on a crime scene, so that future criminal investigations can still be accomplished and their findings used as evidence in court.

Improvised dispersal devices are a special challenge to dispersion calculation systems (DCS), because the mathematical models cannot be specified beforehand but must be altered from incident to incident. A catalogue of generic source term models can be of use and supplemented with a user-interface for easy change of initial settings (for example the diameter of a nozzle on an improvised spraying device or amount of explosive in an IED).
Dispersion in urban settings is particularly challenging for modellers because of the complexity and the high demands on data. New models have in recent years been developed and are being implemented in some available systems. These models increase the demands for the quality of weather data and geographical data on the urban environment, which are unfortunately not available in all European Member States. City dispersion scenarios are highly relevant in relation to bioterror and therefore urban dispersion models should be part of decision support systems.

The health effects on humans used for calculation of casualty estimates depend on the agent's ability to inflict disease, and therefore disease parameters for appropriate agents are important. These parameters are well known for some agents, but for many of them there are no human data available. Also, agents may be manipulated genetically, resulting in unusual symptoms and pathology, making casualty estimates difficult. Often, even the minimal infective dose may not be known. For example for anthrax; it is stated that the LD_{50} for causing disease is 5,000-10,000 spores (Meselson 1994) but experience from the October 2001 anthrax letters (Brachman 2002) and data from the 1979 Sverdlovsk accident indicate that the minimal infective dose may be much lower (Wilkening 2006, Glassman 1966). These uncertainties result in great changes of iso-dose contours, and thus the extent of the hazard area, the cordon sanitaire and the number of persons at risk.

Covert attacks are especially difficult to respond to because the initial attack is not readily identified, only recognizable by the sudden emergence of cases. Wind dispersion calculation models have been speculated to be used but they cannot directly back-calculate from environmental samples and geographical position of cases, to identify the source. But calculations can be made to indicate probable point and time of release. This has been done during a legionnaire's disease epidemic where the source was an air scrubber that accidentally sprayed *Legionella pneumophila* over a large area. The position of cases were plotted on a map, and given the wind direction, it could be made probable which of a number of scrubbers had caused the outbreak. (Nygård 2005).
For an attack with a sufficient number of cases, statistics can be applied to study the relationship between dose response (proximity to the source) and number of cases per capita. This will give some indication of the source and also the extent (area) of the exposed area.

Detailed knowledge of DCS's and their use is essential when using them as decision support tools for preparedness but they can also be used to plan for offensive attacks. A decision support system is therefore a dual-use instrument, and it is essential to restrict dissemination (e.g. security classifications, secure computer networks etc). The training of dispersion calculation experts will supply these persons with sensitive knowledge: knowledge of the effectiveness of dispersion devices and how, where and when an attack is most effective. Access to bio-databases will supply knowledge of agent's ability to cause disease which is a risk, should such information fall into the wrong hands

Dispersion calculation results are approximations to the real world. Dispersion experts must understand the limitations of the dispersion results and higher level decision makers must be aware of these limitations. Evacuation of large areas, involving many people and possibly including critical installations, has large consequences for civil society, both psychologically and economically. Such interventions should therefore be based on the best evidence possible.

Dispersion of hazardous biological material may have transnational consequences: wind and micro organisms do not respect borders. Neighbouring countries will be affected and they may have to institute countermeasures solely based on the investigation and information from the primarily targeted country. The quality of this information should therefore be known, and ideally all European Member States should share information about their capabilities as part of a common preparedness effort. Close collaboration of dispersion calculation experts should be an on-going activity and part of general biodefence training.

Should an incident occur, alerts are communicated via the RAS-BICHAT (Rapid Alert System for Biological and Chemical Agent Attacks) network. Evidence-based input will be communicated to the Health Threats Unit under the EU commission, which coordinates initially via tele-conference within an hour, and subsequently convenes Health Security Committee members at a situation centre in Luxembourg. This will be the communication point for incoming information of details of incidents, including dispersion assessments and the implemented countermeasures in the countries involved. The Health Security Committee will establish common recommendations in order to facilitate harmonization of countermeasures as well as keeping all Member States informed. The Health Threats Unit, the Health Security Committee and individual Member States should be able to draw on experienced dispersion calculation capabilities. Such, highly specialised expertise may be difficult to establish and maintain in all nations. Therefore, it would be preferable to have common dispersal assessment units located in selected places across the European Union.

9. Conclusion

In this report it is described how a dispersion calculation system can be used to assess where an airborne release of biological material will cause hazards. The assessments are produced in real time to support decision makers as an incident evolves. The timeliness of such a system is essential for introducing countermeasures in due time to limit human casualties, civil disruption and economic loss.

The establishment of a unit that can analyse data, produce recommendations, and take action is indispensable for effective response to bioterror attacks. This specialized capability should consist of medical intelligence personnel, a coordination- and modelling group, and field investigators. Such a unit should be able to assess threats in the initial stage of an incident on the basis of continuously updated medical intelligence, and produce recommendations from information gathering and modelling, and subsequently from investigation and analysis of samples from a suspected area of contamination.

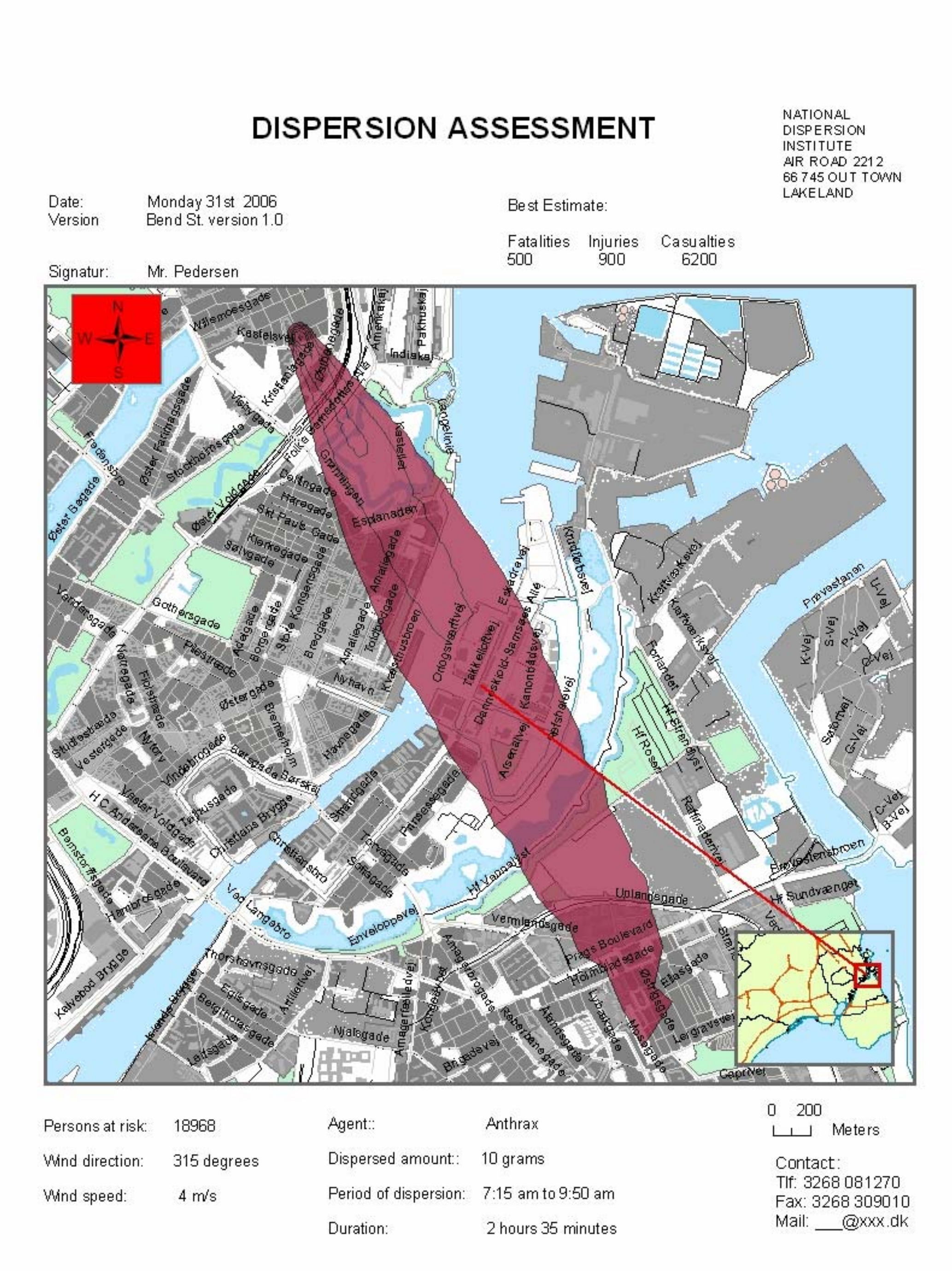
The bioterror scenario in this report makes it evident that response to a biological incident is complex: new information is continuously arriving, requiring new assessments and consequently updated recommendations. The scenario also describes how medical intelligence professionals, field investigators and modellers in combination contribute to the total incident management.

Covert releases are especially difficult to respond to in due time. Many people may already have fallen ill and because the timeline has advanced the ‘window of opportunity’ (i.e. protection, medication, isolation) is shortened. Present dispersion calculation programmes cannot directly back-calculate from actual medical cases to definition of a point of attack. But with further development of the existing dispersion calculation systems it may be possible to estimate the size of area of attack and thus identify the potential further human casualties that would require treatment, when combined with knowledge of disease characteristics and dose response.

An introduction to technical aspects of wind dispersion calculation systems and data needs provides the background for assessing the presently accessible systems. Basically the useful systems are based on puff/plume models using complex meteorological data, terrain data and characteristics of release mechanisms. The assessment in this report indicates that HPAC and NARAC - and with further development also ARGOS – are good candidates for decision support in biological incidents.

In conclusion, an adequate response capability to counter biological incidents requires several components of which wind dispersion assessment is critical. Systems that provide such an assessment capacity are accessible and should be integrated into the operational procedures of individual nations or perhaps on a shared basis between several nations. Further developments of modelling capabilities should provide even better decision support.

10. Dispersion assessment



Dispersion calculation showing location of the contaminated area map features for orientation as well as casualty estimates, wind direction, time and duration.

11. Acronyms and abbreviations

Area of contamination	The area that is contaminated after a cloud of biological material has passed.
Area of exposure	Area wherein a person is exposed to biological material
BSL4	Bio Safety Level 4
CBRN	Chemical/biological/radiological/nuclear
COMA	Coordination of operational and medical assessment
Cordon sanitaire	Cordon surrounding a contaminated area
DCS	Dispersion Calculation Systems (mathematical models compiled into operational systems)
FIT	Field Investigation Team
GIS	Geographical Information System
Hotline	Line between contaminated and not contaminated area
IED	Improvised Explosive Device
Iso-dose	Preset concentration-limit between two adjacent areas with different concentrations. Ex.: boarder line between 5000 inhaled spores and 10000 inhaled spores. Illustrated by contours.
PAR	Persons At Risk
PCR	Polymerase Chain Reaction
Point of release	The exact point where the biological material has been released, it being a letter, explosive, spraying device
NWM	Numerical Weather Model
Scene	Area including point of release and the immediate surrounding area.
Source term	Mathematical model describing the dispersion characteristics at the point of release The source term is determined by the means (weapon) of delivery.

12. References

AEP-45 (A). Programmers Manual for Reporting Nuclear Detonations, Biological and Chemical Attacks, and Predicting and Warning of Associated Hazards and Hazard Areas.

Allwine, K. J. et al. (2002) Overview of URBAN 2000. –A Multiscale Field Study of Dispersion through and Urban Environment. American Meteorological Environment.

Astrup, P.; Thykier-Nielsen, S. and Mikkelsen, T. (2005). In-town dispersion calculation with RIMPUFF and UDM. Risø-R-1539 report. Risø National Laboratory, Roskilde, Denmark.

ATP-45 (B) NATO Allied Tactical Publication 45B, Reporting Nuclear Detonations, Biological and Chemical Attacks, and Predicting and Warning of Associated Hazards and Hazard Areas.

Bork, K. H. Surveillance of ambulance dispatch data as a tool for early warning

Brachman, P. S. (2002) Bioterrorism: An Update with a Focus on Anthrax. American Journal of Epidemiology. Vol. 155, no. 11, pp. 981-987.

Brandt, J. et al. (2002) Modelling transport and deposition of caesium and iodine from the Chernobyl accident using the DREAM model. Atmos. Chem. Phys. Discuss. Vol. 2, no. 3, pp. 825–874.

Bravata, D. M. et. al (2002) Bioterrorism Preparedness and Response: Use of Information Technologies and Decision Support Systems. SMI-2002-0945

Brook, D. R. et al. (2002) Validation of the Urban Dispersion Model (UDM). 8th Int. Conf. on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes.

Brookmeyer R. et. Al (2001). The statistical analysis of truncated data: application to the Sverdlovsk anthrax outbreak. Biostatistics.Vol. 2, pp.233-47.

Chang. J. C. et al. (2005) Use of Salt Lake City URBAN 2000 Field Data to Evaluate the Urban Hazard Prediction Assessment Capability (HPAC) Dispersion Model. Journal of Applied Meteorology. Vol. 44, no. 4, pp. 1882-1886.

Chang, J. C. et al. (2003) Evaluation of CALLPUFF, HPAC and VLSTRACK with Two Mesoscale Field Datasets. Journal of Applied Meteorology. Vol. 42, pp. 453-466.

Cionco, R. M. et al. (1999) An Overview of MADONA: A Multinational Field Study of High-Resolution Meteorology and Diffusion over Complex Terrain. Bulletin of the American Meteorological Society. Vol. 80, no. 1, pp. 5-19.

Cox, R. M. et al. (1998) Wind and Diffusion Modelling for Complex Terrain. Journal of Applied Meteorology. Vol. 37, pp. 996-1009.

Demyanovich, J. (2001) Accounting for the Margin of Error-. NBC Reports. Spring/summer.

Das, D. et al. (2003) Enhanced Drop-in Syndromic Surveillance in New York City Following September 11, 2001. Journal of Urban Health. Vol. 80, no. 2, Supplement 1, pp. i76-i88.

Eidson, M. et. al. (2005) Dead Crow Density and West Nile Virus Monitoring, New York. Emerging Infectious Diseases. Vol. 11, no. 9. www.cdc.gov/eid.

DTRA (2005) The hazard prediction and assessment capability (HPAC) user's guide version. 4.4. Prepared for DTRA by Science Applications. International Corporation, San Diego, USA.

EPI News (2004) Sentinel surveillance of the influenza activity. Epidemiological Department SSI. EPI-NEWS. Vol. 9.

Ermak, D. L. and Nasstrom, J. S. (2000) A Lagrangian Stochastic Diffusion Method for Inhomogeneous Turbulence. Atmospheric Environment. Vol. 34, no. 7, pp. 1059-1068.

Fact sheet. Integration of Dispersion Models. http://www.bruhn-newtech.com/ Accessed July 2006.

Grell, G. A., J. et al. (1995) A description of the Fifth-Generation Penn State/NCAR Mesoscale Model (MM5). NCAR/TN-389+STR, 138 pp., Nat. Cent. for Atmos. Res., Boulder, Colo., USA.

Glassman, H. N. (1966) Industrial Inhalation Anthrax. Bacteriol Rev. Vol. 30, no. 3, pp. 657–659. http://www.pubmedcentral.gov/articlerender.fcgi?artid=378259

Gloster J. et al. (2003) Airborne Transmission of Foot-and-Mouth Disease Virus from Burnside Farm, Heddon-on-th-Wall, Northumberland, during the 2001 Epidemic in the United Kingdom. The Vetenrinary Record. Vol. 152, pp. 525-533.

Grandjean P. and Tarkowski S. (1984) Toxic oil syndrome - Mass food poisoning in Spain. Report on WHO meeting, Madrid, 21-25 March 1983. Copenhagen: World Health Organization, Regional Office for Europe.

Grenco, J. et al. (2003) Clinical Evaluation of the Emergency Medical Services (EMS) Ambulance Dispatch-Based Syndromic Surveillance System, New York City. Journal of Urban Health. Vol. 80, no. 2, Supplement 1, pp i50-i56.

Hall, D.J. et al. (2001) The UDM: A Puff Model for Estimating Dispersion in Urban Areas. 7th Conference on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes. 256-260.

Hanna, S. R. and Chang, C. C. (2004) Use of Urban Field Study Data. The 84th AMS Annual Meeting (Seattle, WA). Sunday Tuesday Monday, 12 January 2004.

Heagy, J. et al. (2004) A Quantitative Comparison of HPAC Predictions and ATP-45 (B) Chemical Templates. Presented at the 8th Intl. Symposium on Protection against Chemical and Biological Warfare Agents, held in Gothenburg, Sweden 2-6 June, 2004.

Hoe, S.; Baklanov, A. and Sørensen, J. H. (2002) Guidelines on the output from the emergency preparedness system for the city of Copenhagen, Denmark. In: Guidelines of output from UAQIFS' as specified by end-users. Ed.: Slørdal, L. H., Norwegian Institute for Air Research (NILU).

Hoe, S. (1997) The Danish nation-wide Nuclear Emergency Preparedness Concept With Special Emphasis on Technical Support Systems. Ministry of the Interior, Emergency Management Agency, Nuclear Inspectorate.

Hodur, R. M. (1997) The Naval Research Laboratory's Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS). Monthly Weather Review. Vol. 125.

Hogan, T. F. and Rosmond, T. E. (1991) The Description of the Navy Operational Atmospheric Prediction System's Spectral Forecast Model. Monthly Weather Review. Vol. 119, pp. 1786-1815.

Inglesby, T.V. et al. (2002) Anthrax as a Biological Weapon. JAMA. Vol. 287, no. 17, pp. 2236-2252.

Kournikakis, B. et al. (2001) Risk Assessment of Anthrax Threat Letters. Defence Research Establishment Suffield. Technical Report. DRES TR-2001-048.

Lauritzen, B. et al. (2003) Atmospheric dispersion of argon-41 from a nuclear research reactor: Measurement and modelling of plume geometry and gamma radiation field. Int. J. Environ. Pollut. Vol. 20, pp. 47-54.

Levin, D. B. and Valadares de Amorim, G. (2003) Potential for Aerosol Dissemination of Biological Weapons: Lessons from Biological Control of Insects. Biosecurity and Bioterrorism. Vol. 1, no. 1, pp. 37-42.

Lober, W. et al. (2003) Syndromic Surveillance Using Automated Collection of Computerized Discharge Diagnoses. Journal of Urban Health. Vol. 80, no. 2, Supplement 1, pp. i97-i106.

Lombardi, J. et al. (2003) A Systematic Overview of the Electronic Surveillance System for the Early Notification of Community-Based Epidemics (ESSENCE II). Journal of Urban Health. Vol. 80, no. 2, Supplement 1.

Lustig, N et al. (2001) Evaluation of Bacillus anthracis Contamination Inside the Brentwood Mail Processing and Distribution Center, District of Columbia, October 2001 Morbid. Mortal. Wkly. Rep. Vol. 50, no. 50, pp. 1077–1079.

Meselson, M. et al. (1994) The Sverdlovsk Anthrax Outbreak of 1979. Science, Vol. 266, pp. 1202-08.

Mikkelsen, T et al. (2003) Investigation of Airborne Foot-and-Mouth Disease Virus Transmission during Low-wind Conditions in the Early Phase of the UK 2001 Epidemic. Atmos. Chem. Phys. Discuss. Vol. 3, pp. 677-703.

Mostashari F. et. al (2003a). Use of ambulance dispatch data as an early warning system for communitywide influenzalike illness, New York City. J Urban Health. Vol. 80, (2 Suppl 1), pp.43-49.

Mostashari, F. (2003b) Dead Bird Clusters as an Early Warning System for West Nile Virus Activity.Emerging Infectious Diseases. Vol. 9, no. 6.

Nasstrom, J. S. et al. (2005) The National Atmospheric Release Advisory Center (NARAC) Modeling and Decision Support System for Radiological and Nuclear Emergency preparedness and Response. International Journal of Risk Assessment and Management. Special Issue: Nuclear and Radiological Emergency Preparedness — The Role of Monitoring and Modeling in an Emergency Situation

Nasstrom, J. et al. (2002) LLNL and SNL Dispersion Modeling and Assessment Tools. Presentation. Lawrence Livermore National Laboratory. American Nuclear Society Winter Meeting, November 18-21. Washington DC.

Nasstrom, J. S. et al. (1999) A Real-Time Atmospheric Dispersion Modelling System. Submitted to the 11th Joint Conference on the Applications of Air Pollution Meteorology with the Air and Waste Management Association, Long Beach, CA, January 9-14, 2000.

Nasstrom, J. S. and Pace, J. C. (1998) Evaluation of the Effect of Meteorological Data Resolution on Lagrangian Particle Dispersion Simulations Using the ETEX Experiment. Atmospheric Environment, 1998

Neuman, S. et al. (2006) Event Reconstruction for Atmospheric Releases Employing Urban Puff Model UDM with Stochastic Inversion Methodology. 6th Symposium on the Urban Environment and Forum on Managing our Physical and Natural Resources.

Nygård, K. et al. (2005) An Outbreak of Legionnaires' Disease Caused by Long Distance Spread from an Industrial Air Scrubber, Sarpsborg, Norway 2005. Presented at the 6th International Conference on Legionella Chicago, Illinois - October 16-20, 2005. http://www.legionellaconf.org/documents/Nygard.pdf

Pobanz et al. (1999) Comparison of Gridded versus observation data to initialize ARAC dispersion models for the Algeciras, Spain steel mill Cs-137 release. American Nuclear Society 7th Topical Meeting on Emergency Preparedness and Response.

Rojas-Palma, C. et al. (2004). Experimental evaluation of gamma fluence-rate predictions from Argon-41 releases to the atmosphere over a nuclear research reactor site. Radiat. Prot. Dosim. Vol. 108, pp. 161-168.

Slørdal, L. H. (Ed.) (2002). Guidelines of Output from UAQIFS' as Specified by End-users. Deliverabal from the Integrated Systems for Forecasting Urban Meteorology, Air Pollution and Population Exposure project.

Ström, J. and Setterberg, B. (Eds.) (1966) Smallpox Outbreak and Vaccination Problems in Stockholm, Sweeden, 1963.

Sugiyama, G. et al. (2004a) Operational Systems for Emergency Preparedness and Response. Publication from: American Meteorological Society, Symposium on Planning, Nowcasting, and Forecasting in the Urban Zone: Emergency Response, 84th Annual Meeting, January 11-15, 2004. http://ams.confex.com/ams/84Annual/techprogram/session_16643.htm

Sugiyama, G. (2004b) National Atmospheric Release Advisory Center (Narac). Model Development and Evaluation..9th Int. Conf. on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes. Chapter 5.40, pp. 177-181.

Sugiyama, G. and Chan, S. T. (1997) A New Meteorological Data Assimilation Model for Real-Time Emergency Response. 10th Joint Conference on the Applications of Air Pollution Meteorology with the Air and Waste Management Association, Phoenix, AZ, January 11-16, 1998.

Sørensen, H. J.et al. (2006) Veterinært Meteorologisk beredskab (VetMet) (in danish). Prepared by Danmarks Meteorologiske Institut, Fødevarestyrelsen, Danmarks Fødevareforskning and Forskningscenter Risø.

Sørensen, J.H. (2003) Modelling the Atmospheric Spread of Foot-and-Mouth Disease. Danish Meteorological Institute scientific report. Copenhagen 2003.

Sørensen, J.H. et al. (2000) An integrated model to predict the atmospheric spread of foo-and-mouth disease virus. Epidemiol. Infect. Vol. 124, pp. 577-590.

Teschke, K. et Al. (2001) Spatial and Temporal Distribution of Airborne *Bacillus thuringiensis* var. *kurstaki* During an Arial Spray Program for Gypsy Moth Eradication. Environmental Health Perspectives. Vol. 109, no. 1, pp. 47-54.

Thykier-Nielsen, S. and Olsen, V. C. Øresund Revisited by RIMPUFF. 8th International Conference on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes, Sofia (BG), 14-17 Oct 2002. Batchvarova, E.; Syrakov, D. (eds.), (Demetra Ltd., Sofia, 2002) pp. 98-12

Thykier-Nielsen, S. et al. (1999) Description of the Atmospheric Dispersion Module RIMPUFF. Paper RODOS (WG2)-TN(98)-02. Risø National Laboratory, P.O. Box 49, DK-4000 Roskilde, Denmark.

Thykier-Nielsen, S. et al. (1993). Experimental evaluation of a pc-based real-time dispersion modelling system for accidental releases in complex terrain. Proceedings from 20th International Technical Meeting on Air Pollution Modelling and its Application, Valencia, Spain, November 29 - December 3., 1993.

Warner, S. et al. (2004a): Comparisons of transport and dispersion model predictions of the URBAN 2000 field experiment. J. Appl. Meteor. 43, 829-846.

Watson, A. and Keir, D. (1994) Information on which to bases Assessments of Risk from Environmental Contamination with Anthrax Spores. Epidemiol. Infect. Vol 113, pp. 479-490.

Webb, G. F. and Blaser, M. J. (2002) Mailborne transmission of anthrax: Modelling and implications. PNAS. Vol. 99, no. 10, pp. 7027–7032.

Wilkening, D. A. (2006) Sverdlovsk revisited: Modelling human inhalation anthrax. Proceedings of the National Academy of Science of the United States of America. Vol. 103, no. 20, pp. 7589-94.