



BRITISH CHEMICAL WARFARE DEFENCE DURING THE GULF CONFLICT (1990-91)

INTRODUCTION

1. When Iraq invaded Kuwait in August 1990, a coalition was formed, initially to prevent further Iraqi aggression, and subsequently to liberate Kuwait itself. From the outset, it was known that the Iraqi regime had been seeking to acquire Weapons of Mass destruction. The large number of casualties resulting from their use of chemical weapons during the Iran-Iraq war of the 1980s, and the attack on Halabja in Northern Iraq in March 1988 had shown that Iraq possessed a Chemical Warfare (CW)¹ capability, and that Saddam Hussein was prepared to use it, both in battle and also against large centres of the civilian population.
2. Although the UK ceased its offensive chemical warfare programme in the late 1950s, ongoing work since the First World War had developed and introduced a suite of measures to defend British forces against the threat of chemical weapons. Further defensive measures were developed during the Gulf conflict itself. These included procedures for warning of and reporting potential and actual chemical weapons attacks; detection and monitoring equipment; individual and collective protection equipment; contamination control equipment; and medical countermeasures.

¹ A glossary of the acronyms used in this report is included at Annex B.

BACKGROUND

3. On 14 July 1997, the Ministry of Defence (MOD) published a policy statement setting out its strategy for addressing the health concerns that have been expressed by veterans of the Gulf conflict.² As part of this strategy, the Government pledged to review incidents during Operation GRANBY where veterans have said that they were exposed to chemical or biological weapons. The first of these reviews concerned a tank of liquid found at the Kuwaiti Girls' School in Kuwait City in August 1991, and a draft case narrative was published jointly by the MOD and the Office of the Special Assistant for Gulf War Illness (OSAGWI) at the US Department of Defense (DOD) on 11 March 1998.³ Another report was published by the MOD on 6 April 1998, and reviewed the circumstances in which UK forces reported the presence of groups of dead animals in theatre during the Gulf conflict.⁴

4. This paper provides background information about the defensive system that was put in place to protect UK troops from the threat of chemical warfare agents, although some elements such as the respirator apply equally to biological warfare agents. This paper pulls together a variety of material about CW defence, some of it previously published. It is the first time MoD has provided a comprehensive picture of the arrangements in the Gulf during 1990/91.

5. Detailed reviews of incidents involving chemical agent alarms, or where veterans have said that they were exposed to chemical weapons will follow. There will be three papers, one investigating the suggestion that a chemical attack took place in Al Jubayl in the early morning of 19 January 1991; second, the release of CW agents after demolition of the Khamisiyah ammunition dump on 10 March 1991; and the third other incidents where it has been suggested that British troops were exposed to Iraqi chemical attacks.

6. A further review will investigate suggested detections of biological warfare agents and will provide a history of the activities of 1 Field Laboratory Unit during the Gulf conflict. This work is now underway.

Related Work

7. On 28 October 1997, the MOD published a paper on the medical countermeasures that were used to protect British troops against Iraqi chemical and biological warfare agents, including Nerve Agent Pretreatment Sets (NAPS) and ComboPens, which protected against nerve agents.⁵ In addition, a Fact-Finding Team has conducted a study into the way in which the anti-biological warfare agent immunisation programme and the administration of NAPS were

² 'Gulf Veterans' Illnesses: A New Beginning', dated 14 July 1997.

³ OSAGWI and MOD Case Narrative: 'Kuwaiti Girls' School', dated 11 March 1998.

⁴ 'Dead Animals During the Gulf Conflict', dated 6 April 1998.

⁵ 'Background to the Use of Medical Countermeasures to Protect British Forces During the Gulf War (Operation GRANBY)', dated 28 October 1998.

implemented in-theatre. A report is being prepared on the basis of their work, and will be published when complete.

8. The MOD has also commissioned a portfolio of research into Gulf veterans' illnesses. This includes a study to investigate the potential health effects of the combination of medical countermeasures that were provided to British troops deploying to the Gulf.

Further Information

9. Further information about the Government's response to the health concerns of Gulf veterans can be obtained from the Gulf Veterans' Illnesses (GVI) web page (www.mod.uk/policy/gulfwar/index.htm). Alternatively, information is available from the Gulf Veterans' Illnesses Unit (GVIU) by calling the GVIU Helpline on 0171 218 4462 or by writing to:

GVIU
Room 8296
MOD Main Building
Whitehall
London
SW1A 2HB.

THE IRAQI CHEMICAL WEAPONS THREAT

The 1990-91 Assessment

10. Following the Iraqi invasion of Kuwait on 2 August 1990, the UK assessed the capabilities of Saddam Hussein's forces. The initial assessment provided by the Defence Intelligence Staff (DIS) set out the CW agents that were thought to be definitely available to Iraq. These were the nerve agents Tabun (GA) and Sarin (GB), the vesicant (blister agent) Sulphur Mustard (H), and the riot control agent CS. Agents assessed as possibly available were the nerve agents Cyclosarin (GF) and VX, the vesicant Nitrogen Mustard (HN), and the blood agent Hydrogen Cyanide (AC). It was also known that Iraq had been provided with information on the utility and weaponisation of the nerve agent Soman (GD), the choking agent phosgene (CG), the psychochemical BZ and the vomiting agent Adamsite (DM). A later assessment in November 1990 noted that the blood agent Hydrogen Cyanide (AC) was now listed as 'probably available', as was dust impregnated with Sulphur Mustard (H)⁶.

11. Iraq was believed to have a stockpile of between 6,000 and 10,000 tonnes of CW agents, and a capacity to produce a further 3,000 to 5,000 tonnes of agent per year. It was thought that this stockpile included more mustard agent than nerve agent.

12. The means of delivering CW agents that were thought to be available to Iraq, included mortars, artillery shells and rockets, and bombs. It was thought that chemical warheads were probably available for Iraqi Ballistic missiles (SCUDs),⁷ and that chemical cluster bombs and air to surface rockets were possibly available. It was also thought possible that Iraq might have projectiles filled with CW agent that they could fire from the one or two long range guns that were thought to be available to them.

13. This information about the assessed Iraqi chemical weapons threat was communicated to the troops in theatre in a CBW Instruction issued by the Joint Headquarters (JHQ),⁸ which was based at RAF Strike Command in High Wycombe. This was sent to the Headquarters British Forces Middle East (HQ BFME), in Riyadh, Saudi Arabia.

⁶ Background information about CW agents, and particularly those mentioned in this report, is included in Annex A.

⁷ Although Iraq has claimed that they fired 93 SCUD missiles during the Gulf conflict, there is no evidence that any of them were fired with chemical warheads.

⁸ The Joint Headquarters (JHQ) was the military headquarters in the UK from where Operation GRANBY was run. The Joint Force Commander, who was based at JHQ, had direct command over the Commander British Forces Middle East (C BFME), who was based at HQ BFME in Riyadh, Saudi Arabia.

Further Information

14. The work that was carried out in Iraq after the Gulf conflict by the United Nations Special Commission (UNSCOM) has shown that Iraq definitely had weaponised Cyclosarin (GF) and VX at the time of the Gulf conflict.

15. In addition, in February 1998 the MOD announced that recently-obtained intelligence had led them to believe that Iraq also possessed large quantities of another CW agent, Agent 15, at the time of the Gulf conflict.⁹

⁹ MOD Statement: 'Iraqi CW Capability During the Gulf War: Agent 15', dated 9 February 1998.

BRITISH CHEMICAL WARFARE DEFENCE AT THE TIME OF THE GULF CONFLICT

Responsibilities

16. At the time of the Gulf conflict, the major responsibility for the formulation of tri-service policy and doctrine in all nuclear, biological and chemical (NBC) matters was the NBC Defence Policy Committee (NBC DPC). This committee was chaired by the 1-star Director of Defence Policy, and its decisions were implemented through a lower level Working Group. There were also staff with responsibility for NBC matters within each of the three Services, DIS and the Operational Requirements branch.¹⁰

Chemical Defence Establishment (CDE)¹¹

17. The Chemical Defence Establishment (CDE) at Porton Down was responsible for research into all areas of chemical and biological defence (CBD), including hazard assessment, detection and monitoring of CW and BW agents, physical protection, contamination control and medical countermeasures. They also undertook tri-Service medical research. In addition to these tasks, CDE developed and produced equipment; provided advice and support to deployed or deploying units, and also to Ministers and other staff within the MOD. The Establishment also carried out a significant amount of operational analysis. CDE's work was overseen by the NBC DPC.

Defence NBC Centre (DNBCC)

18. The Defence NBC Centre (DNBCC) was a tri-Service establishment responsible for all NBC defence aspects of land-based operations. (NBC defence afloat, aircrew personal protection, and other Service NBC matters remained single-Service responsibilities.) The role of DNBCC included training selected personnel from all three Services in NBC defence measures on land; planning and executing trials of NBC defence equipment and procedures; and providing advice on NBC defence training matters to commands, formations and units.

19. During Operation GRANBY, DNBCC worked closely with CDE Porton Down in providing chemical defensive measures for British troops deploying to the Gulf.

¹⁰ The Operational Requirements branch of the MOD play an important role in the procurement of new equipment. They are responsible for setting out the detailed requirement that each new piece of equipment is supposed to meet.

¹¹ CBDE had previously been known as the Chemical Defence Establishment (CDE), but had changed its name immediately after the Gulf conflict. It is now the Chemical and Biological Defence Sector, DERA (CBD Porton Down)

Principles

20. The UK's CW defence at the time of the Gulf conflict was based on several discrete and yet interdependent elements. This was emphasised in the publication *Manual of Nuclear Biological and Chemical Defence Training on Land*:

To ensure that operations continue in an NBC environment, effective NBC defence must be based on a pattern of integrated defence measures.

21. These 'integrated defence measures' included the warning and reporting system that was established to notify the chain of command and neighbouring units of any potential or actual chemical attack; and the chemical weapons detection and monitoring equipment that was developed and deployed. They also included protective equipment to enable individuals and units to survive chemical attack; equipment and procedures to decontaminate personnel and equipment caught up in such attacks; and medical countermeasures that were provided to be taken both in preparation for and after exposure to chemical and biological warfare (CBW) agents. Lastly, these measures included the training that was required to ensure that personnel deployed to the Gulf were able to survive and operate in an environment where the threat of chemical attack was a constant menace. These measures are described in the following sections of this paper.

WARNING AND REPORTING

22. The NATO Allied Tactical Pamphlet 45 (ATP 45), which gave guidance for the warning and reporting of NBC attacks, recognised that such attacks, and the resulting contamination, were 'expected to have a decisive influence on any battle situation'. Commanders required timely and accurate information about these attacks, to enable them to assess the potential impact on their plans and decisions. During the Gulf conflict, therefore, there was a need to ensure that potential and actual chemical attacks were reported up, down and across the chain of command (including to troops from other Coalition nations), and back from the Gulf to military and political commanders and planners at JHQ in High Wycombe and the MOD in Whitehall.

The Warning and Reporting Chain

Theory

23. A warning and reporting chain was set up for Operation GRANBY, based on standard NATO practice and the guidelines set out in the *Manual of Nuclear Biological and Chemical Defence Training on Land*. These guidelines described the establishment of NBC 'Cells' at different levels of command: at unit or source level; then as NBC 'Sub-Collection Centres' and NBC 'Collection Centres' at Brigade or Divisional HQs or RAF Main Operating Bases (MOBs); and finally as NBC 'Control Centres' at command HQs.

24. The functions of NBC Cells were outlined in the *Manual*:

- a. Receive, log and plot NBC information.
- b. Pass immediate warnings to those concerned as soon as an attack is located.
- c. Evaluate the information
- d. Disseminate additional warnings and information as appropriate
- e. Record
- f. Brief staff, or Commander, on NBC implications.

25. NBC Cells were normally commanded by the unit NBC Advisor. This was a HQ officer, such as the adjutant or the operations officer, who would take on responsibility for NBC matters in addition to their other tasks. The NBC Advisor would have received training at DNBC. In addition, the Advisor would normally be assisted by two Junior Non-Commissioned Officers (JNCOs).

Warning and Reporting in the Gulf Region

26. The CBW Instruction that JHQ passed to HQ BFME stressed that commanders at all levels were to set up effective NBC sub-collection centres, with a NBC collection centre at HQ, Brigade and Air Headquarters (AHQ) levels. It was instructed that NBC Cells were to adhere to ATP 45 procedures.

27. In practice, the warning and reporting system in theatre was rather more complex, partly due to the gradual build up of UK forces in theatre, with the arrival of 1 (UK) Armoured Division in December 1990 particularly significant in this respect. This was also due to the organisation of troops within theatre, particularly when they passed through the port of Al Jubayl, which was the entry point into the Gulf for many of the British troops that deployed there. There is only incomplete, and sometimes inconsistent, information available about the warning and reporting arrangements that were put in place. Nevertheless, we can reconstruct some of what happened.

28. In the early days of Operation GRANBY, when the RAF had deployed to the Gulf,¹² NBC matters were the responsibility of a RAF Staff Officer based at the Air Headquarters (AHQ) in Riyadh. When 7 Armoured Brigade (7 Armd Bde) moved out to Saudi Arabia in the days leading up to 3 November 1990, HQ BFME was formed in Riyadh. At the end of December 1990, 4 Armoured Brigade (4 Armd Bde) arrived in theatre, and 1 (UK) Armoured Division was formed. Only at this stage was the NBC Theatre or Zone Control Centre officially moved from AHQ to HQ BFME.

29. The warning and reporting chain used by UK forces in theatre was also tied into the chains used by troops from other Coalition nations.

¹² Royal Navy ships were already deployed to the Gulf on the Armilla Patrol.

30. On the basis of contemporary documentation, and information provided by two officers who played significant roles in the UK's in-theatre chemical defence during Operation GRANBY, we have been able to reconstruct the NBC warning and reporting chain that was established once 1 (UK) Armd Div had arrived in theatre:¹³

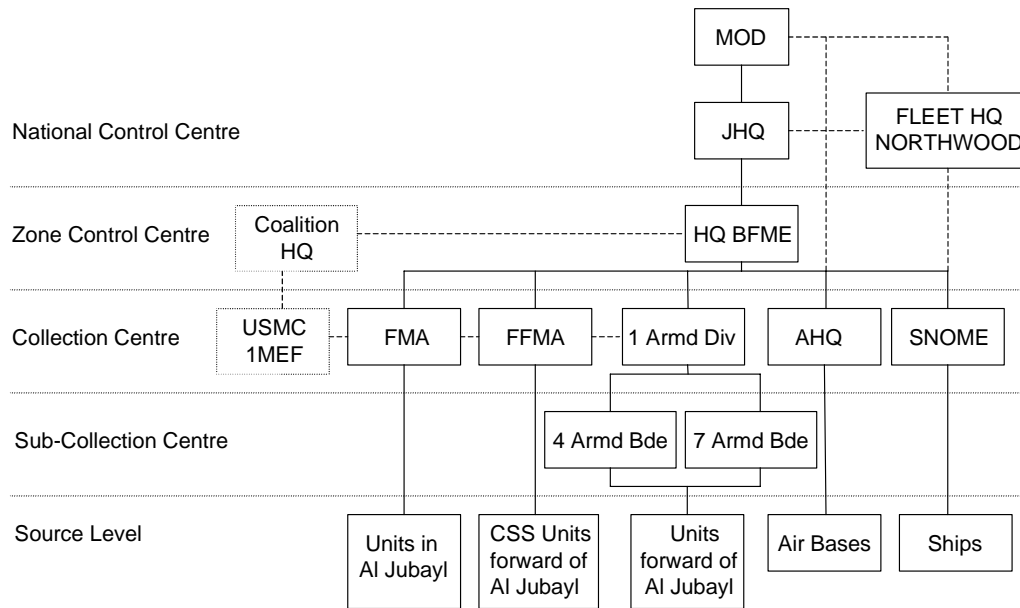


Figure 1: Operation GRANBY NBC Warning and Reporting Chain

¹³ The NBC warning and reporting chain for RN ships was not fully integrated into the chain that was established for Operation GRANBY, with messages for the UK being passed back to Fleet HQ rather than to JHQ. This was partly because ships operate with a very different NBC philosophy to their shore-based counterparts, which meant that orders for forces on land were frequently irrelevant to them.

31. The NBC Cells at each level were responsible for co-ordinating all matters of NBC defence in their area, as the NBC Directive that HQ BFME sent to units in theatre on 15 November 1990 made clear:

Each formation and unit HQ is to establish:

- a. An NBC Cell capable of co-ordinating NBC defence and carrying out the duties of a warning and reporting cell.
- b. An NBC adviser responsible for advising the unit Commander on NBC defence operations, equipment requirements and post-attack options.
- c. Liaison with the NBC organisations of flanking units and formations, including those of other nations.
- d. A coherent NBC defence plan.

32. As the highest-level NBC Cell within theatre, the HQ BFME Cell had wider responsibilities still. These included organising in-theatre NBC warning and reporting, and passing reports that they received upwards to JHQ; providing commanders and subordinate formations within theatre with guidance and advice about all NBC matters; controlling the deployment of NBC equipment within theatre; and controlling the process for the Sampling and Identification of Biological and Chemical Agents (SIBCA – see below) along with other theatre assets.

Warning and Reporting within the UK

33. HQ BFME were under the operational control of the UK Joint Commander, who was based at JHQ in High Wycombe, which was the focal point for communications between the UK and the troops in the Gulf. Within JHQ were 32 functional cells, which were each responsible for different areas of Operation GRANBY. Early in Operation GRANBY, the existing Survive To Operate (STO)¹⁴ Cell was designated the functional cell responsible for overseeing the tri-service NBC matters of Operation GRANBY. Because Iraq had no offensive nuclear capacity, this Cell was renamed the Chemical and Biological Defence (CBD) Cell, although it was frequently still referred to as the STO Cell. This CBD Cell was the sole focus for CBW within JHQ, and processed and evaluated all information from theatre, in order to produce routine reports at 12 hourly intervals for the MOD Central Staffs, with further reports presented as necessary.

34. At a higher level still was the Joint Operations Centre (JOC) in MOD Main Building in Whitehall. This provided the focus for the control of Operation GRANBY that was exercised by the Chief of the Defence Staff (CDS) and the

¹⁴ 'Survive To Operate' is the generic term for the ability of military forces to defend themselves and protect themselves in both conventional and NBC environment, it comprises active and passive defence and recuperation, NBC is a facet of passive defence.

Single Service Chiefs of Staff (COS), who, in turn, took their instructions from Ministers. Like JHQ, the JOC consisted of a number of operational and decision-making cells, one of which was a specialist CBD Cell, which was commanded by the Lieutenant Colonel who chaired the NBC DPC Working Group. The main function of the CBD Cell was to provide information for the principal briefing cells within the JOC, and to assist in the drafting of the NBC-related policy papers that, once approved by the Secretary of State, were transmitted to JHQ and then on to troops in theatre as operational instructions. The Cell also monitored and continually assessed a number of other areas, including morbidity reporting (see below), and the resupply of NBC-related consumables, such as NAPS tablets (see below) and NAIAD and RVD reagents (see below). In addition, the CBD Cell worked with relevant branches and agencies of the MOD, such as CDE and DNBCC, to provide advice and answers in response to requests from JHQ.

Wider Warning and Reporting

35. To ensure that warning and reporting of any Iraqi use of chemical and biological weapons covered a wider area, NATO's Supreme Allied Commander Europe (SACEUR) requested that NATO's Southern Flank Warning and Reporting System was activated. This was done on 21 January 1991, and the system was deactivated on 3 March.

Strengthening of the Warning and Reporting System

36. Although commanders at all levels were instructed to appoint a member of their operational staff as their NBC Adviser, it was generally recognised that many units did not have personnel with sufficient knowledge of operations in a chemical or biological environment, often because they had not sent anyone for the appropriate training at DNBCC for some years. To rectify this problem, staff from DNBCC and RAF units remaining in the UK were sent to the Gulf to act as NBC Advisers and to provide training in NBC matters.

Threat States and Reporting Procedures

NBC Threat States

37. Standard NATO definitions, or Threat States, provided a framework for warning of the general threat of NBC attack.

NBC Threat State	Description
LOW	The enemy has offensive NBC capabilities but there is no indication of their use in the immediate future.
MEDIUM	Nuclear weapons or Chemical/Biological weapons have been used in another theatre of operations and/or there are strong indications that the enemy will use these weapons in the immediate future.
HIGH	Nuclear attack or Chemical/Biological attack is imminent
BLACK	Warning of the imminent arrival of, or presence of chemical or biological agents, or radiological hazards.

38. The CBW Instruction from JHQ and the NBC Directive from HQ BFME made it clear that these Threat States were to be used to warn of the likelihood of Iraqi chemical or biological attack. The responsibility for altering these Threat States lay with the Commander British Forces Middle East (CBFME). Doctrine at the time reflected that local commanders could raise the NBC state, but could not lower it without higher command approval.

Air Raid Warning States

39. In addition, Air Raid Warning States were also defined and disseminated to troops in theatre. These ranged from Warning State WHITE (an attack by enemy aircraft was not immediately probable), through Warning States YELLOW and RED, to Warning State SCARLET (an attack was imminent in the immediate local area). These Warning States could be linked to particular NBC Threat States: WHITE and YELLOW to Threat State LOW; and RED and SCARLET to Threat State MEDIUM. These Warning States, although designed to warn of potential aircraft attacks, were also used in the Gulf to warn of SCUD attacks.

NBC Reports

40. Reports of the use of chemical or biological weapons against British troops were to be sent in accordance with the guidance given in ATP 45. This pamphlet set out a procedure for reporting of attacks and warning of associated hazards that was based around six standard types of message:

NBC 1 - Observers initial report, giving basic data.

NBC 2 - Report used for passing evaluated data.

NBC 3 - Report used for the immediate warning of predicted contamination and hazard areas.

NBC 4 - Report used for passing monitoring and survey results.

NBC 5 - Report used for passing information on areas of actual contamination.

NBC 6 - Report used for passing detailed information on chemical and biological attacks.

41. Any NBC 1 Report informing of the use of chemical or biological weapons was to be passed as quickly as possible, while other reports were to be given a precedence appropriate to the operational value of their contents. For the purposes of Operation GRANBY, the NBC 6 Report was amended so that it could be used for SIBCA (see below) reports.

Means of Warning and Reporting

42. The CBW Instruction from JHQ stated that the primary means of upwards reporting, and of sideways and downwards warning of chemical or biological attacks was to be the RAF's Air Staff Management Aid (ASMA). This electronic communication system was also used for general NBC-related communication, and discrete signal channels, or 'totes', were set aside for different NBC matters, including the six types of NBC Report.

43. Because ASMA, which was normally only used by the RAF, was not universally available, other methods of communication were needed to provide a complete warning and reporting chain for British forces in the Gulf. Radio and telephone were also used, and authorisation was also given for the use of the British Forces Broadcasting Service (BFBS) Radio Middle East for the dissemination of air raid and missile attack warnings and NBC Threat States.

44. Other equipment was also used to supplement the existing warning and reporting system. The Danish Bruhn Data NBC-Analysis system, a software package that could be run on PCs and laptops and which could provide

automated NBC warning and reporting was obtained. This system provided immediate and accurate predications of hazard arrival and clearance times in the downwind area after an attack, and was also used to produce maps for briefing purposes. In addition, the Chemical and Biological Defence Adviser software (CHEBDA), which CDE had been developing prior to Operation GRANBY as a comprehensive system for warning and reporting, was used alongside Bruhn. Although the conflict ended before the complete system could be deployed, CHEBDA was used to provide information and advice to personnel who had little or no knowledge of NBC matters. The limited system deployed to the Gulf aided the user in identifying the class and identity of particular agents; the time taken for the hazards to pass beyond particular locations; the downwind hazards resulting from chemical or biological attacks; and the symptoms and appropriate treatments relevant to particular agents.

Local Warning

45. Obviously there was also a need to provide local warning of probable or actual chemical strikes to those in the attack area. These were to correspond to the warnings used within NATO, and HQ BFME instructed that such local warning was to be provided by 'radio, land-line, audible alarms (e.g. loudspeaker and/or air horn devices) and where practical, visual sign'. The HQ BFME Directive detailed the audible alarms and visual signs that were to be used at different Air raid Warning States and NBC Threat States:

Hazard	Audible Alarm	Visual Sign
Air/Missile Attack Probable	<ol style="list-style-type: none"> 1. Verbal Warning 2. Police vehicle with siren and yellow flag. 	Yellow flags/signs.
Air/Missile Attack	<ol style="list-style-type: none"> 1. Verbal: "AIR ATTACK" or "MISSILE ATTACK". 2. Unbroken warning siren. 3. Long blasts on horns/whistles; 3 seconds on, 1 second off. 	Red flags/signs.
NBC BLACK	<ol style="list-style-type: none"> 1. Verbal: "GAS, GAS, GAS". 2. No siren. Succession of short blasts on horns/whistles. 	Black flags/signs
All Clear	<ol style="list-style-type: none"> 1. Verbal: "ALL CLEAR". 2. Siren for one minute. 3. sustained horn for one minute. 	Removal of flags/signs.

46. In reality, the means of local warning of chemical attacks depended on the options available in each location. Tannoys were set up at the Force Maintenance Area (FMA)¹⁵ in Al Jubayl, and at the RAF base in Muharraq. In some places troops used a combination of a hand-held alarm and megaphone, and air and vehicle horns. Other evidence shows that warnings were simply passed by word of mouth, and the banging of metal on metal, in line with NATO guidance and teaching at the time.

47. From the outset of Operation GRANBY, there was a consensus that a new NBC alarm system was required for use in theatre, particularly because alarms in the Gulf needed to be transmitted over large distances. DNBCC trialled a pyrotechnic warning device, known as a 'maroon', and it was recommended that the maroon used by the UK Warning and Monitoring Organisation could be used as a 'quick fix' solution. These alarms fired in a pattern of three bangs, and were audible over distances of up to one kilometre. The maroons were not fitted with a visual alarm, but this deficiency seems to have been rectified by providing them with flares. It is not entirely clear how many maroon devices were sent to the Gulf, but there is hardly any evidence of them being used. Where they were used, they were extremely effective in gaining attention, but so much so that in Al Jubayl on 19 January 1991, they were thought to have caused great confusion and a number of reports of explosions. As a result maroons were banned from further use in this location, and it was recommended that they were given straight back to the Home Office after the conflict¹⁶.

Conclusions

48. Although there were early problems in setting up a satisfactory warning and reporting system, evidence from post-operational reports suggests that an effective system was eventually achieved. There were complaints from some transport units, whose personnel had been stretched out between several locations in theatre and tended, therefore, to receive information from several sources.

49. On several occasions during and after the Gulf conflict units and individuals were criticised for ignoring the warning and reporting chain. This was due to a number of factors. The different ASMA totes had widespread user access, and it was suggested that they needed to be subjected to tighter control. The key positions in the Operation GRANBY NBC chain of command tended to be filled by RAF officers, and Army personnel in theatre tended to seek advice from those in their own Service, and from DNBCC, where they had been trained. In addition, the need to obtain information quickly from experts meant that there

¹⁵ The Force Maintenance Area provided all of the logistical support that was required to maintain 7 Armd Bde and then 1 (UK) Armd Div.

¹⁶ See A Review of the Alleged Exposure of UK Forces to Chemical Warfare Agents in Al Jubayl on 19 January 1991 to be published in the New Year.

was always a tendency to by-pass a chain that was perceived as being rather slow moving and to go directly to DNBBCC with their questions.

50. Some complications in theatre resulted from operating alongside Coalition forces from other nations. This was a particular problem when troops from 1 (UK) Armd Div were based alongside non-NATO-roled American troops who did not use ATP 45 procedures. This was the case in the FMA in Al Jubayl, which was also the location of a large number of US Marine Corps (USMC) units and personnel. To a large extent, this problem was reduced when 1 (UK) Armd Div came under the tactical control (TACCON)¹⁷ of the US VII Corps on 26 January 1991. There were criticisms that there was not sufficient formal in-theatre liaison on NBC matters between Coalition forces of different nations, and there is evidence that, on a number of occasions, UK troops entered a state of chemical alert just as neighbouring US troops were beginning to relax. However, some Liaison Officers were deployed, particularly in the FMA, and this led to a greater degree of co-ordination and useful sharing of information.

51. It was also suggested that the lack of an executive single focus for CBD matters within the MOD Centre had impaired the resolution of a number of problems and had led to some diffuse direction. But the close liaison that resulted from the regular meetings of the NBC DPC Working Group was seen to have gone some way towards solving this problem.

¹⁷ Tactical Control is a NATO State of Command, which the British Army interpreted as being a situation where the subordinate force had already received its missions and tasks, and the commanding force could only co-ordinate its movement, real estate and local defence.

DETECTION AND MONITORING

Equipment and Procedures

52. There is a distinction between equipment that detects and equipment that monitors the presence of CW agents. Detection equipment is designed for continuous and unattended operation, and is fitted with an alarm to provide warning of a hazard, while monitoring equipment is for use in specific situations where it is already suspected that chemical agents may be present.

53. Prior to the start of Operation GRANBY, different CW agent detectors and monitors were available to UK forces, each of which performed a unique role in the provision of chemical defence.

Nerve Agent Immobilised enzyme Alarm and Detector

54. The Nerve Agent Immobilised enzyme Alarm and Detector (NAIAD) was used to detect and warn of the presence of nerve agent vapour or aerosol, and of attack concentrations of the blood agent hydrogen cyanide (AC). The system comprised a point sampling detector and a remote alarm unit, and was designed for continuous and unattended use. A single detector and alarm unit was designed to be issued to a platoon of 30 men, and was normally sited upwind of their location to provide warning of downwind hazards from upwind attacks, since this was a viable delivery means for nerve agent.¹⁸

55. NAIAD's detector operates in a way that closely mirrors the way that nerve agents attack the human body, by measuring the inhibition of the enzyme cholinesterase.¹⁹

56. It is not clear how many NAIADs were deployed on Operation GRANBY, but CBDE estimated, in one of their post-operational reports, that an average of two were fitted to each of the ships that went to the Gulf; that just over 2,000 were deployed with the Army; and that at least 300 were taken by the RAF.

Residual Vapour Detector

57. Despite its name, the Residual Vapour Detector (RVD) was not suitable for unattended running, but was designed for use once the presence of CW agent was suspected. RVD samples the air to test for the presence of both nerve and mustard agent, but can only test for one type of agent at any one time; not both simultaneously.

58. Although it is a simpler piece of equipment than NAIAD, RVD requires more direct operator activity. It consists of a number of components: four bottles of

¹⁸ There was no comparable detector for blister agent, partly due to the slow pace of technological development in this field, and partly because blister agent was considered unsuitable for downwind attacks.

¹⁹ For detailed information about how nerve agents work, see Annex A.

liquid (two of which are used to test for nerve agent and two for mustard); pieces of detector paper (or 'tickets'); and a rubber bulb, or adapter.

59. To test for nerve agent the first of the appropriate bottles must be crushed, thus releasing and mixing chemicals in capsules inside the bottles. A drop of liquid must then be applied to a ticket slotted into the adapter. The adapter must be squeezed and released 30 times by the operator, which causes air to pass through the ticket. A drop of liquid from the second bottle must be applied to the ticket, which will then turn blue. It must then be warmed under the armpit for two minutes. If the ticket remains blue nerve agent is present. If it turns white nerve agent is absent. The chemistry behind RVD's detection of V-agents is similar to that of NAIAD, and is based on the inhibition of cholinesterase.

60. The test for mustard agent is similar. A drop of liquid from the first bottle should be applied to the ticket and the bulb squeezed 30 times. If any colour shows at this point, mustard agent must be assumed to be present. However, if the ticket remains white, it should be warmed for two minutes, before a drop of liquid from the second bottle is applied. A mauve or purple colour at that point indicates the presence of mustard agent, while a yellow or brown colour may indicate the presence of some other agent.

61. There is evidence that some 6,000 of these sets were provided to units deploying to the Gulf.

Detector Papers

62. There were two types of detector paper in use at the time of the Gulf conflict. These indicated the presence of liquid chemical warfare agent by changing colour, and were used both to provide an initial warning of chemical attack, and then to locate contaminated areas.

63. Detector Paper No.2 (One Colour) was issued to individuals. It had a pressure sensitive adhesive on its reverse side, which meant that it could be attached to an NBC suit or personal weapon, or even to the side of a trench or vehicle. The paper's neutral colour was green, but any part that came into contact with chemical warfare agent would turn navy blue.

64. Detector Paper No. 1 (Three Colour) was issued at Section level.²⁰ This was used to provide additional information about the type of liquid chemical warfare agent causing contamination, and would be used as ordered by local commanders. One colour paper was an off-white colour before use, and would change colour when in contact with a liquid chemical agent: mustard agent would turn it red, G-nerve agent yellow, and V-nerve agent green.

²⁰ A section consisted of eight to ten individuals, and there were three sections to a platoon.

Chemical Agent Monitor

65. The Chemical Agent Monitor (CAM) was designed for use after a suspected chemical attack, to search for and locate nerve and blister agent contamination on personnel, equipment or the ground. It was also used for monitoring the boundaries of collective protection (COLPRO – see below).

66. CAM was a hand-held point monitor, with a push button control to select between nerve and blister agent mode. A Liquid Crystal Display (LCD) indicated the mode in which CAM was working by showing either the letter 'G' (nerve agent) or 'H' (blister agent). The concentration of agent present was indicated by displaying between one and eight bars. CAM worked by ionising air and molecules of other vapours entering the unit and then classifying the ionic clusters according to their relative mobility.

67. Evidence, again from one of CBDE's post-operational reports, indicates that some 200 CAMs were deployed with the Navy; 3,000 with the Army; and 500 with the RAF.

Extending the Capability of the Chemical Agent Monitor

68. At the time of Operation GRANBY, NAIAD was the only real detector that was available to British troops. However, NAIAD would not respond to some of the CW agents that were thought to be at Iraq's disposal. As a result there was no detector capable of warning of the presence of Sulphur Mustard, Nitrogen Mustard, Phosgene, Adamsite, CS and BZ. Although CAM would respond to the presence of Sulphur Mustard and Nitrogen Mustard, it was not designed for continuous and unattended operation and was not fitted with an alarm to provide warning of a hazard.

69. This problem was recognised in the earliest days of Operation GRANBY. On 20 August 1990, CDE advised that modifications to CAM's software would give it the ability to respond to all of the potential Iraqi threat elements, and that other 'add-ons' would allow it to be used as a warning detector. These proposals were carried forward, and a number of variants on the basic CAM were obtained or developed for deployment to the Gulf region.

GRANBY CAM

70. In liaison with Graseby Ionics, who manufactured CAM, CDE developed software that allowed CAM to respond to all of the potential Iraqi threat agents. Software to reprogramme 290 CAMs was ordered at the end of October 1990, and a technician from the Royal Electrical and Mechanical Engineers (REME) was trained at CDE and deployed to the Gulf to carry out the required modifications. CAMs that were programmed with this new software were known as 'GRANBY CAMs'. These modifications did not proceed as planned in the months up until January 1991, rather fewer than 290 GRANBY CAMs were actually used in the Gulf. Additionally, Army NBC advisers did not consider it

operationally viable to retrain operators at such a late stage in the deployment, with offensive land operations about to begin.

Field Alarm Module

71. Like CAM, the Field Alarm Module (FAM) was manufactured by Graseby Ionics, and could be attached to CAM with only minor software modifications. FAM included a remote alarm module giving visual and audible warning, as well as a normal LCD display, and could switch automatically between G- and H-mode. Its disadvantage was that it could only operate in one mode at one time, and there would be relatively long periods of time when the system could not alarm while it switched from one mode to another. The RAF were the only Service to obtain and deploy FAM, which they planned to have collocated with NAIAD and permanently switched in H-mode. They used some 40 FAMs during the conflict.

CAM Remote Alarm and Display Unit

72. The CAM Remote Alarm and Display Unit (CRADU) was designed for use at sea, and provided a remote readout capability for CAMs fitted to the bridge wings of ships. CRADU had been fitted to the ships that had been on the Armilla patrol in the Gulf in the years before Operation GRANBY. The Royal Navy chose to use CRADU during the Gulf conflict, as an interim measure while the Reconfigured Graseby Ionics Detector (see below) was being developed and procured. A total of 68 CRADUs were fitted to ships, at an average of two per ship.

CAM Remote Alarm and Display Unit Mk II

73. The CAM Remote Alarm and Display Unit Mark II (CRADU 2) was developed from the earlier CRADU, and was based on a series of CAMs connected to a single Remote Alarm Display, with different CAMs running in G- and H-modes. CDE suggested several ways in which CRADU 2 could be used, from the standard use with a CAM to provide a remote alarm to the use of a series of pairs of CAM and CRADU 2 linked to a central computer to provide networked detectors over distances of up to one kilometre, thus allowing coverage of static locations such as airbases, where the computer would be able to identify which CAM had alarmed, which agent it had detected, and the approximate concentration of that agent. Up to approximately 600 CRADU 2s appear to have been produced during Operation GRANBY, with some 400 of these actually sent to theatre.

74. CRADU 2's versatility was demonstrated by the way that it was used in the development of a mobile ground reconnaissance unit. The requirement for such a unit was due to the delay in the delivery of FUCHS (see below). Two pairs of CAMs, at differing heights from the ground, were fitted to the Combat Vehicle Reconnaissance (Tracked), with each pair connected to CRADU 2s, and both

CRADU 2s linked to a Master Control Unit. This arrangement was able to detect ground areas that were contaminated with liquid chemical warfare agents.

Other Detection Systems and Related Processes

75. In addition to NAIAD, RVD, the two detector papers, and CAM and its variants, some other types of detection equipment had been in use before the start of the Gulf conflict, while some new equipment was brought into service.

76. Equipment that had been in existence for some time included the Kit Water Testing, Poisons (KWTP), which was designed to determine whether water supplies in the field were safe to drink, and the Explosive Ordnance Disposal (EOD) Kit, which was designed for use by EOD personnel in determining the contents of a suspected chemical weapon prior to its disposal. Both the KWTP and the EOD Kits taken to the Gulf had been badly neglected so that some of their constituent parts and chemicals had been allowed to fall out of date.²¹

77. The Reconfigured Graseby Ionics Detector (RGID) was a reconfigured version of the Ship Installed Chemical System (SICS Mk 10 NHA), which was still in development when the Gulf conflict broke out. RGID could detect both nerve and mustard agents, as well as some of the other agents that Iraq was believed to possess. It was first deployed to the Gulf in early January 1991, and a total of 12 units were used during Operation GRANBY.

78. In addition to these more technical types of equipment, there is evidence that at least one Royal Navy ship and one Army unit obtained birds for use as detectors of CW agents. However, these probably had little use beyond being simple morale raisers, since there were doubts whether the birds would have died quickly enough to serve as a warning to the service personnel.

79. The most significant item of new detection equipment that was obtained during Operation GRANBY was the German FUCHS vehicle, which was a light armoured NBC reconnaissance vehicle, with a number of on-board detection systems. Eleven of these vehicles were given to the UK by the German government, who also provided such vehicles to the US, who renamed them 'FOX' vehicles. By the close of hostilities, only six of these FUCHS vehicles had arrived in theatre. There is no evidence to suggest that any of the British FUCHS that reached the Gulf were ever used in the tasks for which they were provided, although the American FOX vehicles were used on a number of occasions.²²

²¹ The EOD Kit was used by British EOD personnel in the initial testing of the tank of liquid that was found at the Kuwaiti Girls' School in August 1991 (see OSAGWI and MOD Case Narrative published on 11 March 1998). It is not clear whether the chemicals in the kit used on this occasion had been replaced shortly before use, or whether they were out of date.

²² Two American FOX vehicles were used in the incident at the Kuwaiti Girls' School (see the OSAGWI and MOD Case Narrative dated 11 March 1998).

Sampling and Identification of Biological and Chemical Agents

80. It was recognised that the first use of CBW agents during Operation GRANBY would have been a matter of strategic importance. It would have been essential to prove the use of such agents beyond reasonable doubt. To then inform the military and political response to such use; so that the international forum could be notified through the UN. Hence that appropriate medical countermeasures could be prepared; and support to possible prosecutions for war crimes at a later date. Since observations on the battleground would constitute only circumstantial proof, there was a need to take samples from the area of any alleged attack and to return these to a laboratory for analysis, all the while maintaining an irrefutable audit trail.

81. Prior to the Gulf conflict, the UK had been discussing how to implement a process for the sampling and identification of biological and chemical agents (SIBCA), in accordance with NATO STANAG 4359.²³ Right at the start of Operation GRANBY, such a system was established. CDE developed SIBCA kits, which were despatched to theatre in September 1990, and, in liaison with DNBCC, drew up operating instructions. These instructions listed the types of sample that were required. These ranged from munitions fragments, which were most useful, through environmental samples, such as soil or vegetation, and contaminated equipment and clothing, to biological samples, such as blood, urine, or dead animal matter, which were given the lowest priority.

82. Samples taken from the sites of alleged chemical or biological attacks were to be returned to CDE, and analysis conducted, wherever feasible, and within 24 hours. A Chemical and Biological Agent Technical Evaluation Board (CBATEB) was formed to oversee the handling and testing of these samples on arrival at CDE. The SIBCA process was tested in an exercise that took place at the end of November 1990, when samples were sent to Porton Down from 7 Armd Bde and the RAF bases at Dhahran and Muharraq.

83. It is unclear how many SIBCA kits were sent to the Gulf, but seems likely that approximately 50 were deployed with the three Services. Evidence suggests that these were issued to Army HQs and RAF detachments, but not to individual units.

Morbidity Reporting

84. At the start of Operation GRANBY, a morbidity reporting system was implemented among British troops in the Gulf, to catalogue the signs and symptoms of those personnel who reported sick. Analysis of the results might have enabled the recognition of previously undetected use of chemical or biological weapons. It was planned to obtain data from units on a daily basis, which would be consolidated in theatre and sent back to the UK every week.

²³ A 'STANAG' is a NATO Standardisation Agreement. These are issued to ensure the standardisation and interoperability of equipment used by NATO member countries.

There were some problems in obtaining this data, partly because Army units were frequently dispersed over a wide area, particularly when 1 (UK) Armd Div was moving up to the Forward Force Maintenance Area (FFMA).²⁴ This meant that no information was received from Army units 'during deployment' (presumably when they were forward of Al Jubayl). Nor was information received from ships when they were in the northern Gulf.

85. Despite these problems, some morbidity data, particularly from units in the FMA, RAF detachments and some RN Ships, was sent back to the UK from the end of October 1990 until mid March 1991. There is no evidence that any of this data led to any concerns that chemical or biological attacks might have taken place.

False Positive Detections

86. Documents surviving from the time of Operation GRANBY indicate that there were many occasions when units reacted to non-existent threats from CW agents. These tended to occur more often in the early days of the deployment, while forces were still adjusting to their new circumstances and to the Iraqi chemical and biological weapons threat. Some of these problems were caused by the fact that very few of the personnel who deployed to the Gulf had any previous experience of using the detection and monitoring equipment.

87. NBC training correctly emphasised the need to take protective measures whenever an alarm took place. The propensity of equipment to give false alarms in certain circumstances was not covered in training as this might lead to casual attitudes to alarms with disastrous consequences in the event of a genuine CW attack. However, this approach to training had the effect of persuading many Gulf veterans that their equipment would only respond to real CW agents. It is likely that many veterans who experienced alarms in the Gulf believed, and still believe, that they were experiencing a real chemical attack.

88. It is therefore important, in the context of assessing particular incidents to understand that alarms might often have gone off in 1990/91 in circumstances where CW agent was not present. Problems associated with the use of detection and monitoring equipment fell into two particular categories. The first were false alarms, when equipment reacted to substances other than CW agents; and the second were simple equipment failures. (These problems have been addressed since 1990/91 with progressive improvements to equipment and procedures.)

²⁴ The logistics base for 7 Armd Bde, and then 1 (UK) Armd Div, was known as the Force Maintenance Area (FMA), and was located in Al Jubayl, with many units from the United States Marine Corps (USMC), with whom 1 (UK) Armd Div were originally intended to fight. However, when it was decided that the British Division would fight with the US VII Corps, who were based closer to the Iraqi border, a Forward Force Maintenance Area (FFMA) was set up, some 300 km to the north east of Al Jubayl, near Al Qaysumah.

False Alarms

89. Chemical agent detection and monitoring equipment can respond to the presence of substances other than those they are designed to identify. The substances that cause false alarms are known as 'interferents', and many of these were known before Operation GRANBY as a result of field trials and laboratory testing; some were even used as 'confidence testers', to check that the equipment was working, or to simulate the effects of CW agents for training purposes. However, some interferents that had been previously unknown were discovered during the Gulf conflict. Some examples are given below. Others remain classified for operational reasons.

Nerve Agent Immobilised enzyme Alarm and Detector

90. In 1990/91 NAIAD was known to respond to a number of interferences. These included the high explosives Amatol 80 and 90; high concentrations of chlorine, nitrogen dioxide and sulphur dioxide; cyanide (e.g. cigarette smoke); and other organophosphorous compounds (e.g. pesticides).

Residual Vapour Detector

91. It was known, before the Gulf conflict, that fly spray would cause RVD to give a false alarm, and this substance was, therefore, used for training purposes. Experiences on Operation GRANBY led to the realisation that aerosolised liquid hydrocarbons; the expended rocket motor from a downed SCUD; and the lubricating oils OX28, OM100, and OMD 85 would also cause false alarms.

Detector Papers

92. Three colour detector paper had previously been known to give a false response in the presence of oil of cloves and Diethyl Amino Ethanol, but tests at CDE during Operation GRANBY indicated that both one and three colour papers would show positive results for certain lubricating oils and hydraulic fluids. It was also observed in theatre that Inhibited Red Fuming Nitric Acid (IRFNA), which was used as a fuel oxidiser in SCUD missiles, would give a blue indication on one colour detector paper.

Chemical Agent Monitor

93. In 1990/91 a number of harmless substances were known to give a false response on CAM. These included aromatic vapours, such as some brands of aftershave and perfume, and breath tainted by peppermints and cough lozenges; cleaning compounds; and fumes from the Challenger Armour Piercing Discarding Sabot (APDS) round or ammunition for the Mark VIII Naval 4.5 inch gun.

94. Towards the end of 1990, investigations at unit level showed that CAM would give a response in aircraft, particularly around dense molecular material such as glass or Perspex. It was later discovered that CAM would also respond to

IRFNA, while it was reported that the equipment would also give a false alarm in the presence of sewage.²⁵

Equipment Failures

95. Some of the equipment failures that affected the performance of the detection and monitoring equipment that was deployed to the Gulf were due to the unusual desert environment of the Gulf, while others were the result of user error.

Nerve Agent Immobilised enzyme Alarm and Detector

96. NAIAD was well equipped for fault detection. A number of Light Emitting Diodes (LEDs) were fitted to the operator control panel, and would illuminate to indicate the existence of particular problems. In addition, the equipment was fitted with a fault condition alarm, although this may have led to some confusion as operators mixed this up with the standard warning alarm.²⁶

97. The dusty Gulf environment was a cause of concern regarding the use of NAIAD, and there were fears that this would compromise the equipment's rapid response to nerve agent vapours. Those handling NAIAD were advised to keep the inlet tube clean and to change the equipment's enzyme pad at frequent intervals. Environmental shields were also introduced into service.

98. It was thought that a high proportion of the many NAIAD failures that were reported as occurring during Operation GRANBY were due to user error. The equipment was not always flushed out or closed down correctly after use. When NAIAD was powered by batteries that had previously been used with a Clansman Radio, its performance was affected. There were also problems caused by poor stock-keeping: many of the chemical reagents and enzyme pads that were provided were out of date. The fact that the enzyme pads needed to be replaced more often than normal, and that the high temperatures of the Gulf region were thought to reduce the lifetime of these pads, meant that this shortage of NAIAD consumables became a real problem. As a result, 1 (UK) Armd Div ordered that Army units were not to activate NAIAD below the Threat State NBC MEDIUM.

Residual Vapour Detector

99. Most of the problems with the RVD involved the reagent sets that were contained in the plastic bottles. Many of these sets were well past their shelf life, even though this lifetime was extended from 10 to 15 years for Operation GRANBY. Replenishment kits do not appear to have been provided, and troops used out of date reagents on a number of occasions. As has been described

²⁵ For an example of a CAM responding to IRFNA, see the OSAGWI and MOD Case Narrative: 'Kuwaiti Girls' School', dated 11 March 1998.

²⁶ There is also evidence that the hand-held alarm provided for local NBC warning was confused with NAIAD's alarm, as was the temperature alarm on the blood banks at 32 Field Hospital. Also the sound of the warning tone emitted by the device fitted to vehicles to indicate the vehicle is reversing.

above, these reagents were activated by crushing the capsules inside the glass bottles, and users frequently failed to do this properly before use.

100. There is also evidence that troops were using RVD tickets to carry out tests on liquid samples, by applying the liquid directly to the test paper, which would not have provided meaningful results. RVD is intended to test for chemical agent vapour.

Detector Papers

101. Stocks of detector papers appear to have been rapidly exhausted, and troops had to resort to using papers that had lost their self-adhesive capability. However, it must be emphasised that this did not in any way affect their ability to actually detect chemical warfare agents.

Chemical Agent Monitor

102. There were also problems with CAM. The monitor had been fully specified for use in temperatures of up to 45°C, but 'in the shade' temperatures in the Gulf exceeded this, although CDE advised, on the basis of environmental trials, that CAM would function in the G-mode at temperatures of up to 55°C and in the H-mode at temperatures of up to 50°C. There were also rumours that sand had caused CAM to fail.

103. Other CAM failures were caused by excess moisture in the monitor's recirculating system. It was assessed that this was related to the amount of time for which the units had been held in storage, and to their previous history of use. As a result, it was advised that only CAMs with later serial numbers should be issued to the Gulf. CAMs with earlier serial numbers were sent for repair. To combat the same problem, it was also advised that CAMs were to be given a 12 hour run-in period prior to use, to ensure the removal of any moisture or contamination. However, there was a lack of suitable batteries for use with CAM, and units were unwilling to use the batteries that they did have for this purpose. In addition, the normal lithium battery only had a lifetime of 10 hours, which was not ideal for a 12 hour run-in. These problems were solved by the provision of special power supply units for use while conditioning CAMs.

Summary

104. There were differing views about the success of the detection and monitoring equipment used during Operation GRANBY. NAIAD was severely criticised for its complexity, and particularly for its high number of false alarms. RVD was not seen as a success, mainly because so many of its components had been out of date. The basic CAM was viewed as a success, although its incompatibility with COLPRO and the lack of suitable batteries caused significant problems.

105. A large number of the difficulties that were experienced were caused by poor stock keeping and management of the supply chain. This led to two particular problems. Firstly, neither Army units nor War Maintenance Reserves had sufficient scales of detection and monitoring equipment, particularly in the case of units deploying later in Operation GRANBY who had been 'robbed' by the units that had deployed at an earlier stage. And, secondly, the equipment that was held was often suspect because the vital consumables were out of date.

106. There were gaps in the UK's CW agent detection capability, particularly at the start of Operation GRANBY. There was, initially, no detection capability for a number of the agents that it was thought might have been in the Iraqi capability. Of special concern was the lack of equipment capable of detecting blister agent, even after amendments had been made to CAM. However, one colour detector paper worn on IPE would have indicated the presence of blister agent. However, problems might have arisen had troops entered into an area that was contaminated by liquid blister agents, where the amount of vapour given off by the liquid might have been too small to trigger a CAM being used as a mobile detector.

PROTECTIVE EQUIPMENT

107. Another element in the UK's defensive response to the threat posed by Saddam Hussein's chemical weapons threat was the provision of equipment to protect personnel from the actual presence of CW agents. This included both protection for individuals and for groups of personnel.

Individual Protective Equipment

108. Individual Protective Equipment (IPE) is the personal clothing and equipment that is given to individuals to protect them from chemical and biological hazards and from nuclear effects. At the time of the Gulf conflict, standard IPE for UK ground-based forces included the S10 Respirator, the No 1 Mk 4 NBC Suit, NBC Gloves, NBC Overboots, and the Facelet. In addition, it included two personal decontamination kits, one colour detector paper, NAPS tablets and the ComboPen.²⁷

S10 Respirator

109. The S10 Respirator was the most important item of IPE, protecting the eyes, nose, throat, lungs and facial skin from CBW agents, and from radioactive dust. The respirator consisted of a facepiece on which was mounted a canister that filtered the intake of air through charcoal and paper filters. The face piece also incorporated a Primary Speech Module, which provided an outlet valve through which individuals could speak and a drinking device, and a Secondary Speech Transmitter that could clip onto a Clansman microphone. When it was not in use, the respirator was carried in a haversack.

No 1 Mk 4 NBC Suit

110. The NBC Suit included a jacket and trousers, which were made of a lightweight non-woven fabric that was specially treated to make it resistant to chemical warfare agents. The outside of the fabric was covered by a more durable, woven material, which encouraged the rapid spreading and evaporation of the liquid agent, and the inside by a layer of fine charcoal, to counteract vapour hazards.

111. The suit was designed to be worn over at least one layer of outer clothing (such as a normal combat suit), along with underwear to cover the armpits and the crotch (this ensured that perspiration was absorbed by the clothing and did not reduce the ability of the charcoal lining to absorb chemical vapour).

²⁷ The personal decontamination kits are described below, under 'Contamination Control', while NAPS and ComboPen are described under 'Medical Countermeasures'.

NBC Gloves

112. IPE included two pairs of gloves. The inner cotton pair was worn beneath the cuffs of the NBC suit jacket, with the outer neoprene pair worn over these cuffs. Worn together, the gloves provided three hours protection against liquid chemical agents, and 24 hours protection if they were decontaminated within 15 minutes of exposure. They gave indefinite protection against chemical vapour.

NBC Overboots

113. NBC Overboots were made of impermeable butyl rubber, and could be worn over any standard military footwear. They were to be worn under the trousers of the NBC suit. They would provide 24 hours protection against chemical contamination.

Facelet

114. The Facelet was designed to be worn by personnel who would not be able to mask up within nine seconds of an alert, and whose task would have been severely hindered by the wearing of a respirator before a chemical hazard was actually present. The Facelet consisted of layers of charcoal cloth that were held in place over the nose and mouth by elasticated straps, and provided only a limited level of protection against the inhalation of nerve agent.

IPE in the Gulf Conflict

115. It was recommended that individuals deploying to the Gulf were equipped with one respirator with three canisters, three NBC suits, six pairs of both inner and outer gloves, and three pairs of overboots.

116. The CBW Instruction that was issued by JHQ on 18 October 1990 defined the different dress states for UK forces deployed on Operation GRANBY:

NBC Dress Categories	Meaning
ZERO	No NBC IPE worn
ONE	Wear NBC suit (hood down)
TWO	Wear NBC suit (hood down) and overboots
THREE	Wear NBC suit (hood up) overboots and gloves (inner and outer)
FOXTROT	Wear facelet
ROMEO	Wear respirator

117. The Instruction also included recommendations about the levels of IPE that were to be worn at each of the NBC threat levels:

NBC Threat Level	Dress Category: In Open	Dress Category: Under Cover	Dress Category: In COLPRO
Low	ZERO	ZERO	ZERO
Medium ²⁸	ONE	ONE	ZERO
High	THREE	TWO	ONE
NBC State Black	THREE ROMEO	THREE ROMEO	ONE ROMEO

118. Because the IPE provided for British troops had been designed for use in Central Europe, there were problems when personnel were expected to wear it in the hot climate of the Gulf, where it could lead to heat stress, psychological casualties, and degradation in individual performance. This was particularly so when IPE had to be worn in combination with Combat Body Armour, which was being worn in combat for the first time. Since wearing IPE in the Gulf could have such serious effects on personnel, JHQ, prompted by CDE and DNBCC, provided detailed advice to troops in theatre about the amount of work that could be expected from individuals in different IPE dress states at different temperatures. They also provided guidance about the amount of water that would be required by individuals in these situations. As an example, it was recommended that, in temperatures greater than 30°C, personnel engaged in heavy work should only work for periods of five to ten minutes, with rest periods of 15 to 30 minutes. Personnel in these circumstances required at least 15 litres of water each day.

119. Reflecting the above factors and standard doctrine, which included a 'Risk Taking Philosophy', the final decision as to the level of IPE to be worn was placed on appropriate field level commanders. This allowed commanders to balance the assessed risk of enemy chemical activity and other elements of the enemy threat against the requirement to achieve operational tasks.

Conclusions

120. Post-operational reports indicate that the IPE worn by UK Service personnel emerged from the Gulf conflict with its reputation enhanced. There were some minor problems with IPE, several of which were due to poor stockholding, meaning that stores had to be taken from units in the British Army of the Rhine (BAOR) and UK Land Forces (UKLF) in order to provide two NBC suits for every person deployed to the Gulf, but the equipment gained the confidence of the UK forces.

²⁸ Notwithstanding this instruction there is evidence that the standard procedure in theatre was dress state zero at medium threat level.

Collective Protection

121. NATO defines collective protection (COLPRO) as 'protection provided to a group of individuals in a nuclear, biological and chemical environment which permits relaxation of individual ... protection.' Therefore it provides an environment, either within a static shelter or a vehicle, within which individuals can remove their IPE.

122. COLPRO was provided for two main reasons: to provide a protected environment for operations, medical and other staff who could not perform their tasks in IPE; and to give all personnel an opportunity to rest from wearing IPE.

123. COLPRO consisted of a number of components. Its central feature was an airtight Toxic Free Area (TFA), with an overpressure inside to prevent vapour from seeping in through any cracks in the lining. Air from outside was ducted into the TFA through Air Filtration Units (AFUs) that removed chemical and other contamination. Entry into the TFA was via the Contamination Control Area (CCA), which was separated from the TFA by an Airlock. Both the CCA, Airlock and entry drills were designed to minimise the contamination entering the TFA.

124. COLPRO systems could be hardened or semi-hardened, if they were purpose built at permanent locations, to give full protection against ballistic and NBC attack. Unhardened COLPRO (UCP) provided no such protection against blast, heat, fragmentation, and only short term protection from direct liquid attack. It could afford some protection against the effects of radiation, in particular alpha particles. Instead, UCP was designed to protect personnel from chemical and biological warfare agent vapours and aerosols. It was therefore used in areas where this was judged to be the most likely hazard. Mobile COLPRO systems were those that were fitted to vehicles, such as the Challenger 1 Main Battle Tank and Transportable Container Bodies.

Collective Protection in the Gulf Conflict

125. Two types of UCP were in service at the start of the Gulf conflict: the airlock Porton Liner System, and the Porton Modular System. The former was a transportable COLPRO facility used by aircrew and their ground support staff. It was designed to hold around eight personnel and was erected either under a basic shelter or inside buildings for added protection. The latter, which could be used to build up large COLPRO complexes, was used in medical facilities. This enabled medical and surgical care to be given to casualties in a toxic free, filtered air environment.

126. There was, however, a need to provide more COLPRO, since the high temperatures in theatre would limit the amount of time for which IPE could be

worn.²⁹ As a result, the 25-man Winterbourne Liner, which was originally designed for use by the RAF, was brought into service, where it both supplemented and replaced the Porton Systems that were used by the RAF and the medics. The 25 man Winterbourne Liner was a lightweight transportable liner and was originally designed to provide personnel without existing COLPRO with a light, versatile facility for rest and relief. Designed to be erected under existing shelter it could be installed and inflated very quickly and equally rapidly deflated. Winterbourne ISO liners were also provided. These were used inside some of the many empty ISO containers that had been used for transporting equipment to the Gulf, and thus provided a degree of ballistic protection, and some protection from liquid chemical agents.

127. In addition to the new equipment that was provided, amendments were made to existing equipment. For example, new casualty airlocks, long enough to receive stretcher-borne casualties, were provided for use with UCP liners.

128. A range of AFUs were deployed to the Gulf, with filters that were modified to offer a better level of protection against CW agents. There was a need to carry out regular checks on all of the filtration equipment deployed to the Gulf to prevent them from becoming clogged with sand.

129. Although personnel in COLPRO were not subject to the same level of heat degradation as those in IPE, concerns were voiced that those who worked in COLPRO for extended periods of time when there was no direct chemical threat, such as medics, did suffer a significant degradation in performance. As a result, a number of air conditioning units (ACUs) were also deployed to the Gulf.

Conclusions

130. The deployment of COLPRO to the Gulf was also hindered by supply problems. At the start of Operation GRANBY, COLPRO had only been available for RAF and medical units. Although some additional COLPRO had arrived in the Gulf before the end of hostilities, many units appear to have made a conscious effort not to draw from this, due to the implications for manpower, transport and other resources. Units generally preferred to carry water, rations and ammunition, rather than COLPRO. However, COLPRO was certainly relied on extensively at 22 and 32 Field Hospitals, largely due to the nature of their role involving the treatment of casualties, many of whom would be incapable of donning IPE.

²⁹ However, it was also noted that these high temperatures would have the effect of reducing the persistency of chemical agents, and contamination times, and so some felt that there was little need to provide COLPRO for Rest and relaxation facilities.

CONTAMINATION CONTROL

131. Contamination control is defined as 'procedures to avoid, reduce, remove, or render harmless ... nuclear, biological or chemical contamination for the purpose of maintaining or enhancing the efficient conduct of military operations.'

132. At the time of the Gulf conflict, the UK's policy on contamination control was based on two primary measures: avoidance and decontamination.

Avoiding Contamination

133. The simplest means of contamination control was obviously to avoid such contamination altogether. But this doctrine recognised that this would not always be possible, since operational demands could make it necessary to knowingly expose troops and equipment to this hazard. Nevertheless, a number of measures were available to reduce the risk of contamination.

134. These measures included the use of overhead cover, such as hardened shelters and buildings; clearly marking contaminated areas, so that they could be avoided; and careful route planning to avoid picking up contamination in transit. In addition, Chemical Agent Resistant Material (CARM) was also deployed to the Gulf. This was designed for use as an overhead cover, to protect from liquid CW agents. It was much appreciated by users, although this may have been more because it was successfully used in other ways, for example as a simple sunshade or groundsheet.

Decontamination

135. Where contamination could not be avoided, doctrine recognised that it would sometimes be necessary to carry out decontamination, which sought to speed the natural reduction of the hazard that would occur through weathering. At the time of Operation GRANBY, British doctrine was based around operational decontamination, where equipment would be decontaminated only to the extent that was necessary to allow the operation to carry on, with troops then continuing to wear IPE and fight 'dirty'. Thorough decontamination was only to take place when it was absolutely essential that troops should be able to unmask quickly. In addition, the higher temperatures in the Gulf meant that CW agents would be absorbed into surfaces more quickly, and that the resulting residual vapour hazard would also fall more rapidly. Therefore, it was recommended that it was only worth decontaminating the surfaces of equipment if free liquid was still present.

136. Chemical agents on equipment could be neutralised by scrubbing the surfaces with chlorine-based decontaminants, or could be removed by steam cleaning or simply washing them off with water. The Karcher Multipurpose Decontamination System (MPDS) was provided to Army and RAF units

deploying to the Gulf, in order to provide them with dry steam, hot water and blasted fullers earth,³⁰ and therefore a capability for thorough decontamination.

137. One means of easing the process of decontaminating equipment is to provide it with a surface that does not easily absorb CW agents, although, as noted above, this was not judged to be such a problem in the Gulf environment. Although it was suggested that all vehicles deploying to the Gulf from BAOR should be painted with Chemical Agent Resistant Coating (CARC), which is a non-absorbent polyurethane paint, the assessment was that the difficulties of doing this outweighed the benefits. Vehicles were therefore deployed with alkyd paint, which would readily have absorbed such CW agents had they been used.

138. Two personal decontamination kits were included as part of IPE. The first (DKP No 1 Mk 1) consisted of four sachets, each including a cloth pad that was sown together in a loop and filled with fullers earth. These were used to absorb CW agents from the skin and personal equipment. The second (DKP No 2 Mk 1) was a plastic bottle filled with fullers earth, that was designed to 'puff' powders into contaminated areas that were otherwise hard to reach.

³⁰ Fullers Earth was a substance that removed chemical warfare agents from a surface by absorbing them.

MEDICAL COUNTERMEASURES

139. The effects of exposure to chemical warfare agents may be reduced and/or prevented by a combination of treatment before and after exposure takes place. In consequence, UK troops who deployed to the Gulf were provided with medical countermeasures for both pre- and post-attack treatment. These were another of the suite of standard defensive measures that were deployed to protect UK troops against Iraqi chemical warfare agents.³¹

ComboPen

140. The effect of nerve agents on the human body is described in Annex A, but, broadly speaking, nerve agents work by inhibiting the enzyme acetylcholinesterase. This enzyme breaks down the acetyl choline at nerve-nerve and nerve-muscle junctions in the peripheral and central nervous systems. The effects of nerve agent poisoning, therefore, are to cause seizures within the brain, excessive contractions of the skeletal and visceral muscles and excessive secretions in the airways.

141. In the event of nerve agent poisoning, post-attack treatment requires the administration of three drugs: Atropine, P2S (pralidoxime mesylate) and Avizafone. These were administered by the ComboPen, which was an automatic injector containing a sterile aqueous solution of atropine sulphate, P2S and avizafone. The ComboPen was to be self-administered by intramuscular injection into the thigh as soon as a casualty showed symptoms of poisoning, and was to be followed by a second and third dose at 15 minute intervals, as required. ComboPens were carried as part of IPE.

142. Atropine acts to block the effects of nerve agents at nerve-nerve and nerve-gland junctions and consequently it reduces seizure activity in the brain and excessive secretion of fluid in the airways. P2S is an oxime that reactivates acetylcholinesterase that has been inhibited by some nerve agents; it has limited effectiveness for Tabun and Cyclosarin and unless administered immediately has no effect against Soman. Avizafone is a water soluble drug that is rapidly converted to diazepam by the body; it acts to limit seizure activity and control muscle convulsions by suppressing nervous activity in the brain and by acting as a muscle relaxant.

Nerve Agent Pre-treatment Set

143. The ComboPen, which provided post-attack treatment in the event of nerve agent poisoning, was one defensive measure for troops facing a chemical

³¹ Further information about the use of medical countermeasures can be found in the MOD paper 'Background to the Use of Medical Countermeasures to Protect British Troops during the Gulf War (Operation GRANBY)', published in October 1997. In addition, a Fact-Finding Team has conducted a study into how the anti-biological warfare agent immunisation programme and the administration of NAPS were implemented in-theatre. A report is being prepared on the basis of their work, and will be published when complete.

threat. But it is also possible to administer pre-treatment to troops in this situation.

144. Research indicated that pyridostigmine bromide (PB) would provide protection against exposure to all nerve agents, including Soman. PB mimics the action of nerve agent by binding to acetylcholinesterase at exactly the site that would be attacked by a nerve agent. Therefore, PB effectively prevents the nerve agents having access to the enzyme, and thus prevents the enzyme from being irreversibly inhibited. However, unlike nerve agent, PB only binds to acetylcholinesterase temporarily. Within minutes a proportion of acetylcholinesterase that has been protected by PB will regenerate spontaneously. The standard dose of PB protects approximately 30% of the total acetylcholinesterase in the body from being inhibited by nerve agent, so that this amount of enzyme is available to be used for the restoration of nerve transmission. The human body will survive if this proportion of its acetylcholinesterase remains free.

145. Therefore, it was decided to use PB as a pre-treatment to protect British troops from poisoning by all nerve agents. NAPS tablets consist of 30mg doses of PB, and are to be taken orally every eight hours.

146. NAPS is not an alternative to the ComboPen. Both treatments are to be used in the event of a nerve agent threat and actual poisoning. When used in advance of poisoning NAPS increases the level of protection provided against Tabun (GA), Soman (GD) and Cyclosarin (GF) and enhances the condition of survivors of poisoning by Sarin (GB).

NAPS and Operation GRANBY

147. During Operation GRANBY, the authority for instructing personnel to take NAPS was delegated to the Commander British Forces Middle East (CBFME).

148. The decision to start taking NAPS appears to have been taken on 18 January 1991, although there is evidence that personnel in the FMA began to take NAPS the day before. Also on 18 January, JHQ High Wycombe warned that all personnel waiting for definite deployment to the Gulf should start taking NAPS 48 hours prior to their arrival in theatre, and, on 21 January, JHQ gave permission for forces out of theatre to start taking NAPS as well.

149. It is not entirely clear why the order to start taking NAPS was given on 18 January 1991. However, it is likely that this was in response to Iraq's first use of SCUD missiles. The first SCUDs were fired by Iraq at approximately 03:00 hours (local time) on 18 January. It is likely, therefore, that the decision to start taking NAPS was prompted by this particular threat, and by the threat that these SCUDs could carry chemical warheads.

150. It appears that troops in theatre were given permission to stop taking NAPS on 1 March 1991, and commands in the UK were told that troops about to deploy to the Gulf could cease taking NAPS on 4 March.

TRAINING

151. It would not have been effective to have provided individuals and units deploying to the Gulf with the equipment and procedures outlined above if they were not sufficiently trained to make good use of them. From the start of the Operation, it was recognised that there was a significant need for training in CBD, particularly among troops from the British Army of the Rhine (BAOR). It was assessed that this training shortfall was the greatest deficiency in the chemical defence arrangements for British forces, and one that meant that, at the start of the Operation, some BAOR units would not have been able to fight without sustaining severe chemical casualties. This situation was even worse among the units that deployed to the theatre at a later stage as part of 1 (UK) Armd Div.

152. There was, therefore, a need for thorough training at unit level. This was recognised in the HQ BFME NBC Directive, which ordered that individual and collective training should take place as soon as possible after arrival in the Gulf. As a result, all units passing through the Force Maintenance Area (FMA) in Al Jubayl,³² were given NBC training and advice about NBC equipment and warning measures. Special training was also provided to NBC Cell operators. In addition, troops from 1 (UK) Armd Div received pre-deployment training before their departure from Germany. The requirement for NBC Instructors was met, in the main, by personnel from DNBCC.

153. It was the assessment of those involved in the provision of chemical warfare defence for Operation GRANBY that this training effort went some way towards achieving the desired effect, and it was predicted that the survival rate after any chemical attack would have been high. However, there were still doubts about the degree to which troops were familiar with and had confidence in the equipment that they were using.

³² Al Jubayl, where the FMA was based, was the port of entry for many of the UK troops who were deployed to theatre.

CONCLUSIONS

154. Although the Iraqi chemical weapons threat was little different to the threat that had been presented by the Soviets, the specific environment of the Gulf meant that CBD for Operation GRANBY was not necessarily straightforward. Standard Operating Procedures were focused on withstanding attacks in central and northern Europe, and were not immediately applicable to Out of Area regions such as the Persian Gulf.

155. It was recognised at the time of Operation GRANBY that the ability of the UK forces to defend against a chemical threat varied from unit to unit. To an extent, this was inevitable. It will always be easier for those who deal with small numbers of discreet, self-contained and permanent, or semi-permanent, installations, such as airbases and ships, to employ tidier solutions to the problems posed by a chemical threat, than for those responsible for large numbers of scattered and mobile units. As a result, the Royal Navy and the RAF were better equipped to survive any chemical attack than their Army counterparts.

156. Nevertheless, these problems were largely overcome through a combination of initiative and hard work. Because the UK's chemical defence was based on a number of interdependent and complimentary measures, this synergistic effect overcame some of the individual weaknesses that have been highlighted.

CHEMICAL WARFARE AGENTS

Introduction

1. CW agents are chemical compounds which, when suitably disseminated, produce incapacitating, lethal or damaging effects on man, animals, plants or materials. Humans are vulnerable to such agents by inhalation, ingestion, or absorption through the skin.

The Physical State of Chemical Warfare Agents

2. CW Agents can present a toxic hazard in four physical forms: true gases or vapours; liquid aerosols (mist); solid aerosols (smoke); and liquids.

3. Liquid agents will either be volatile, with high vapour pressures and low boiling points, or non-volatile, with low vapour pressures and high boiling points. Volatile agents are called 'non-persistent' agents, since they vaporise on dissemination and will be carried away on the wind. Non-volatile agents are 'persistent' agents, and will contaminate target areas for longer periods of time.

4. Non-persistent agents are normally employed to provide a cloud of toxic vapour over, or within, a target area, in a concentrated attack in which surprise is an important element, with the intention of achieving a rapid 'knockout' effect. Non-persistent clouds of vapour attack individuals through the respiratory system, and thus the S10 respirator will provide good protection against this threat.

5. Persistent agents are usually disseminated as a liquid, in order to contaminate personnel, ground and equipment, and therefore make the wearing of IPE essential, since liquid agents can penetrate the skin. Because liquid agents also present a vapour hazard, the respirator must be worn as well.

Classification

6. Agents can also be classified according to their physiological properties, highlighting how the toxic chemical acts on the human body and the resulting symptoms exhibited by the victim. These classifications include:

- **nerve agents**, which interfere with the nerve pathways between the brain and the voluntary muscles, thus leading to muscular spasms and paralysis;
- **vesicant agents (blister agents)**, which produce very painful blisters on the skin
- **blood agents**, which interfere with the handover of oxygen from the blood to the body tissues;
- **choking agents**, which attack the lungs, causing them to fill with liquid;
- **nose agents (vomiting agents)**, which lead to sneezing and vomiting;
- **tear gases (riot control agents)**, which produce temporary incapacitation by attacking the eyes
- **psychochemical agents**, which disorientate the mind, and produce hallucinations and irrational behaviour.

7. Agents can also be classified in terms of the extent of the damage that they are likely to do to a human, as lethal, incapacitating or damaging.

Toxicity and Dosage

8. A chemical agent will not cause serious harm to an individual unless a certain minimum dose has been absorbed. Agents vary greatly in their potency, and thus some are effective in much smaller doses than others.

9. For a vapour cloud or aerosol presenting a respiratory hazard, the exposure can be conveniently expressed as the product of the agent concentration (C) and the exposure time (t), which is known as the 'Haber Product', or 'Ct' exposure, with units of milligrams minutes per metres cubed ($\text{mg}\cdot\text{min}\cdot\text{m}^{-3}$).³³ Since the susceptibility to CW agents varies from human to human, it is not possible to specify an exact minimum effective dosage or lethal dose for each agent. As a result, scientists can only define the dosage that has a specified probability of producing a particular effect. It is possible to define the term 'Effect Ct_{50} ' (ECt_{50}) which indicates the Ct exposure that has a 50% probability of producing some kind of an effect. The 'Incapacitation Ct_{50} ' (ICt_{50}) is the exposure with a 50%

³³ For greater accuracy, the Ct exposure should be defined as the integral of concentration against time ($\text{Ct} = \int \text{C}(t) \cdot dt$) which allows for instances where an individual is exposed to a concentration of agent that varies over time.

probability of incapacitating the victim.³⁴ If the effect is death, then this is known as the 'Lethal Ct₅₀' (LCt₅₀).³⁵

10. In almost all cases, the body has a very limited ability to dispose of toxic chemicals, and dangerous dosages can be accumulated during a relatively long exposure. For nerve agents the effects of poisoning can be cumulative. This means that over periods from a few minutes up to many hours the Haber product is approximately constant. Thus it may be as dangerous to inhale a small concentration for a long time as it is to inhale a high concentration for a short time.

Doses

11. Although they may appear to be interchangeable terms, there is a distinction between the 'dosage' of a CW agent to which a person is exposed (which can also be termed the 'exposure'), and the 'dose' that is taken into the body. A dose is simply measured in units of mass (micrograms or milligrams).

12. To calculate the dose of agent that is inhaled, it is necessary to multiply the exposure dosage by the breathing rate of the exposed individual. This breathing rate is measured in litres (L – or m³) per minute, and increases as the level of activity of the individual concerned increases. It is the level of the dose, and not the dosage, that determines the extent to which an individual is harmed, and therefore the ECt₅₀, ICt₅₀ and LCt₅₀ values for each agent are calculated assuming a particular breathing rate for the individuals concerned.

13. For example, if a man were walking at 2.5mph through an agent vapour at a constant dosage level of 0.150 mg.min.m⁻³, he would be breathing at a rate of approximately 30 litres per minute (0.03 m³.min⁻¹). Therefore, providing that the entire dose that he inhaled was retained in his body, he would inhale a dose of 0.0045 milligrams (0.150 x 0.03), or 4.5 micrograms (µg).

14. The dosage of sarin estimated to kill 50% of the human population (LCt₅₀) is between 50 and 70 mg.min.m⁻³ (see below). A man walking through this dosage at 2.5mph and breathing at 30 Lmin⁻¹ would inhale and retain a dose of between 1.5 and 2.1 milligrams of sarin. So this figure represents the lethal dose of Sarin for 50% of the population by inhalation.

³⁴ The dosage of an agent that will prevent an individual from performing the tasks assigned to them will vary from circumstance to circumstance. For example, slight miosis caused by a low dosage of agent will incapacitate a fighter pilot, while having little effect on an infantryman.

³⁵ It must be stressed that the values of ECt₅₀, ICt₅₀, and LCt₅₀ are estimates, extrapolated from the doses found to have these effects on animals.

Chemical Agents Assessed as Part of the Iraqi Threat during Operation GRANBY

15. This section sets out information about those agents that have been assessed, either in 1990 or in the years since then, as part of the Iraqi chemical weapons threat during Operation GRANBY. The agents are categorised according to their physiological properties (as set out above).

Nerve Agents

16. Nerve Agents are a group of highly toxic chemical agents that are derived from phosphorous. Broadly speaking, there are two types of nerve agents. So called G agents are the more volatile and present a respiratory and a percutaneous threat. So called V agents are less volatile but are able to penetrate the skin. Thus, as liquids, they present a percutaneous hazard. Additionally, V agents can be inhaled if they are present in the air as a vapour or as aerosol particles.

17. To explain the effects of nerve agents, it is necessary to understand something of the workings of the human nervous system. The brain controls muscular function by emitting electrical impulses that result in the release of acetylcholine at the neuromuscular junctions, stimulating the muscle to contract. It is then destroyed, by hydrolysis, by the enzyme acetylcholinesterase, thus allowing the muscle to relax.

18. When nerve agents enter the body, they inhibit cholinesterase, thus decreasing the amount that is available at the neuromuscular junctions. This allows the levels of acetylcholine to rise, thus causing excessive contraction and seizing up of the muscles.

19. Exposure to a low dose of nerve agent causes symptoms of minor poisoning including a strong contraction of the pupil (miosis), which impairs the ability of individuals to undertake tasks where excellent vision is essential. Exposure to higher doses can result in the following symptoms: increased salivation, running nose, difficulty in breathing, increased perspiration, vomiting, diarrhoea, involuntary discharge of urine and defecation, cramps and convulsions. There may also be effects on the central nervous system. Death may result from respiratory failure caused by paralysis of the respiratory centre in the central nervous system and of the respiratory muscles.

20. The time for symptom progression varies with the concentration of agent present. If a lethal amount of agent is absorbed through the skin, it may be some hours before the first symptoms are noticed. Large vapour doses, however, may cause unconsciousness within minutes.

Vesicant Agents

21. Vesicant agents (blister agents) are not usually lethal, but are designed to damage the body by burning and blistering the skin. They can also cause casualties if they are inhaled while in a liquid or vapour state. The most significant vesicant agents are the 'mustards' (sulphur mustards and nitrogen mustards) and the organoarsenicals, typified by Lewisite.

22. Sulphur Mustard (H or HD), in its liquid form, acts on the skin to destroy tissue, and thus to cause severe blistering. As a vapour, it attacks the eyes, the respiratory tract, and any moist areas of the body. There can often be a period of several hours after exposure before symptoms begin to appear.

23. Some six to 12 hours after a dose of mustard in the eyes the first symptoms will appear. These will include marked conjunctivitis, local oedema (an excess of watery fluid collecting in the cavities or tissues of the body), blepharospasm (a complete closure of the eyelids, caused by a muscle spasm), lacrimation (the secretion and discharge of tears), and severe eye pain. If the exposure is severe, and drops of liquid agent actually enter the eye, effects will be seen after only a few minutes, and intense pain will be felt. After some hours, necrosis of the cornea (changes indicative of cell death caused by the degrading action of enzymes) will develop with deep ulceration. Blindness will result and will take months to heal. In some cases there may be perforation of the cornea and loss of eye contents.

24. The effects of mustard on the skin vary from itching and painful inflammation to the formation of large, liquid-filled blisters, but these effects only become apparent after several hours or even a day. Oedema will occur in the affected areas, which may also be marked by necrosis and blistering of the skin and subcutaneous tissue. Damaged areas may take several weeks to heal. This is because mustard destroys the enzymes that promote genetic material replication, and therefore slows down cell division and the rate at which healthy flesh can grow to cover an injury.

25. The inhalation of a high concentration of vapour, even for only two or three minutes, will result in symptoms that will become apparent within anything from a few hours to a day. Initial symptoms include mucosal irritation, 'dry cough', sore throat and hoarseness, and will be followed by inflammation of soft tissues and vocal cords. Severe chest pain, destruction of the lining of the trachea, secondary respiratory infections and lung abscesses may follow. Very severe exposure can lead to death through lung oedema.

26. The ingestion of mustard causes abdominal pain and flatus to occur very rapidly. Pain and inflammation will develop later in the mouth and throat. After a few hours, bloody vomiting, diarrhoea and shock may develop. Fifty milligrams of mustard ingested orally will cause death in about two days.

27. There may also be other symptoms. The nervous system can be affected by massive doses of mustard, while, since mustard is an alkylating carcinogenic, effects similar to those resulting from radiation exposure may also be seen. There may be damage to the bone marrow lymph nodes and the spleen, while any resulting drop in white blood cells will make the casualty very susceptible to secondary infections.

Nitrogen Mustard

28. Nitrogen mustards are a family of compounds related structurally to Sulphur Mustard. The effects that they have on the human body are similar to those described above. They act more quickly on the eye, but do not have such a powerful effect on the skin.

Blood Agents

29. The most common blood agent is Hydrogen Cyanide (AC). This agent can cause death very rapidly at high concentrations. However, Hydrogen Cyanide differs from some other CW agents in one important respect. It may have no effect at low dosages, because the body's defence mechanisms can detoxify cyanides fairly rapidly. Therefore, at concentrations below this natural detoxification level the poison cannot accumulate in the body.

30. Blood agents act extremely rapidly to prevent the body using oxygen. They interfere with oxidative phosphorylation processes in the cell and at nerve membranes and also poison the enzyme cytochrome oxidase that is involved with transfer of oxygen between the blood and the tissues.

31. The first symptoms of blood agent intoxication may be feelings of weakness, headaches, constrictions in the throat, giddiness, confusion and, in some cases, nausea. Respiration may be stimulated at first, but will then become weak and finally cease. Exposure to higher concentrations may cause violent convulsions, and will lead to unconsciousness within 30 seconds.

32. Those who die of high doses of blood agents will typically have a pink-flushed look to the skin and reddish lips, caused by a build up of oxygen-rich blood in the veins since it takes longer for oxygen to pass from the blood to the tissues. Where the poisoning is less severe, the opposite effect will be observed and the victim will have bluish-coloured skin. This is because breathing will have been slowed down to an insufficient level that even the arterial blood is starved of oxygen.

Choking Agents

33. Phosgene is a typical choking agent, and attacks the body's respiratory tract. Severe phosgene poisoning can lead to the development of long oedema, as the inhaled agent damages the capillaries in the lungs and allows watery fluid to seep into the air cells. If a large amount of the agent is inhaled, these air cells

will become flooded, and the victim will 'drown' due to the lungs being filled up with fluid, and from lack of oxygen. Physical exertion will only serve to increase this effect. The full effect of this poisoning is normally not seen until three or four hours after exposure.

34. The symptoms that will eventually be seen begin with coughing and choking, which will be followed by an inability to expand the chest, hurried and shallow breathing, and sometimes vomiting. Final stages include severe chest pain, blueness of the lips and the face becoming either bloated red or greyish-coloured.

Vomiting Agents

35. Vomiting agents are non-lethal agents that cause severe physical distress to the victim. They are solids, and are dispersed as 'smokes' or solid aerosols.

36. Because its LC_{t50} is so much higher than its IC_{t50}, Adamsite was formerly used as a riot control agent, but is now generally regarded as being too toxic for this role.

37. Exposure to minute amounts of Adamsite leads to irritation of the nose and throat, then of the eyes, and then of the chest, with a growing sense of suffocation. There will be excessive nasal secretion, ropy saliva and nausea. Prolonged exposure may lead to aching pains in the stomach and numbness in the limbs. It is considered highly unlikely that Adamsite could cause death under field conditions.

Riot Control Agents

38. Like Adamsite, the LC_{t50} of CS is far higher than the IC_{t50}, and therefore CS gas has been used as a riot control agent for many years. The gas causes an intense smarting of the eyes, a burning sensation in the nose and throat, and a tightness of the chest. These effects are immediate on exposure.

Psychochemicals

39. Some of the most effective incapacitating agents are those that act on the brain and the central nervous system, causing mental disturbance and rendering individuals incapable of discharging military duties. These effects may last for hours or days after exposure.

40. Agents such as BZ or Agent 15, depress or block the activity of the central nervous system, often by interfering with the transmission of information across synapses. These agents appear to block the action of acetylcholine in the same way as atropine.

41. After exposure to BZ or Agent 15, symptoms appear about 30 minutes after inhalation, build up to a maximum in four to eight hours, and then subside

gradually over a few days. Peripheral symptoms appear first, including a parched mouth and throat, and dry flushed skin. Vision will then blur, and dizziness and disorientation will develop. There will be difficulty in co-ordinating various muscular functions and possibly the experience of visual and muscular hallucinations, thus destroying the ability to perform any military task. Some individuals may display maniacal activity.

Physical Characteristics of Chemical Agents Assessed to be in the Iraqi Threat During Operation GRANBY

42. The table below sets out the physical characteristics of those CW agents known or believed to have been part of the Iraqi chemical weapons threat during the Gulf conflict:

Agent	Melt. Pt (°C)	Boil. Pt (°C)	Vapour Pressure (mm Hg)	Vapour Density ³⁶	Physical Characteristics
Tabun (GA)	-50	246	0.035 (20°C)	5.6	Colourless to brown liquid; faint almond odour
Sarin (GB)	-56	158	2.1 (25°C)	4.9	Colourless (pure) to black liquid (crude); odourless
Soman (GD)	-42	198	0.4 (25°C)	6.3	Light liquid; fruity camphor-like odour
Cyclosarin (GF)	<-30	239	0.05 (25°C)	6.2	Colourless liquid; possible sweet fruity odour
VX	<-50	298	0.00066 (20°C)	9.2	Colourless to straw-coloured liquid, with fluidity of motor oil; odourless
Sulphur Mustard (H)	14	228	0.072 (20°C)	5.4	Colourless (pure) to dark (impure) liquid; garlic odour
Nitrogen Mustard (HN3)	-4	137-138/15 mm Hg	0.0071 (20°C)	6.9	Colourless liquid which darkens on storage; fish or soap-like odour
Hydrogen Cyanide (AC)	-14	26	610 (20°C)	0.93	Very volatile liquid; odour of bitter almonds
Phosgene (CG)	-118	8	1173 (20°C)	3.4	Colourless to yellow gas; odour of mown hay
Adamsite (DM)	195	410 (decomposes)	Negligible – too low to be of significance	9.6 (forms little vapour)	Green to dark brown solid; aromatic odour
CS	94	310	0.000034 (20°C)	6.5 (forms little vapour)	White solid; pepper-like odour
BZ	164-167	320	0.0000014 (20°C)	11.6 (forms little vapour)	White odourless solid

³⁶ The vapour density of air is 1.

GLOSSARY

AC	Hydrogen Cyanide (Blood Agent)
ACU	Air Conditioning Unit
AFU	Air Filtration Unit
AHQ	Air Headquarters
APDS	Armour Piercing Discarding Sabot
ASMA	Air Staff Management Aid
ATP	Allied Tactical Pamphlet
BAOR	British Army Of the Rhine
BFBS	British Forces Broadcasting Service
BZ	Psychochemical Agent
CAM	Chemical Agent Monitor
CARC	Chemical Agent Resistant Coating
CARM	Chemical Agent Resistant Material
CBATEB	Chemical and Biological Agent Technical Evaluation Board
CBD	Chemical and Biological Defence
CBDE	Chemical and Biological Defence Establishment
CBFME	Commander British Forces Middle East
CBW	Chemical and Biological Warfare
CCA	Contamination Control Area
CDE	Chemical Defence Establishment
CDS	Chief of the Defence Staff

CG	Phosgene (Choking Agent)
CHEBDA	Chemical and Biological Defence Adviser
COLPRO	Collective Protection
COS	Chief Of Staff
CRADU	CAM Remote Alarm and Display Unit
CRADU 2	CAM Remote Alarm and Display Unit Mk II
CS	Riot Control Agent
CSS	Combat Service Support
CW	Chemical Warfare
DIS	Defence Intelligence Staff
DKP	Decontamination Kit Personal
DM	Adamsite (Vomiting Agent)
DNBCC	Defence Nuclear Biological and Chemical Centre
DoD	Department of Defense
EC _{t50}	Effect Ct ₅₀
EOD	Explosive Ordnance Disposal
FAM	Field Alarm Module
FFMA	Forward Force Maintenance Area
FMA	Force Maintenance Area
GA	Tabun (Nerve Agent)
GB	Sarin (Nerve Agent)
GD	Soman (Nerve Agent)
GF	Cyclosarin (Nerve Agent)

GVIU	Gulf Veterans' Illnesses Unit
H/HD	Sulphur Mustard (Vesicant Agent)
HN	Nitrogen Mustard (Vesicant Agent)
HQ BFME	Headquarters British Forces Middle East
ICt ₅₀	Incapacitation Ct ₅₀
IPE	Individual Protective Equipment
IRFNA	Inhibited Red Fuming Nitric Acid
JHQ	Joint Headquarters
JNCO	Junior Non-Commissioned Officer
JOC	Joint Operations Centre
KWTP	Kit Water Testing Poisons
LCD	Liquid Crystal Display
LCt ₅₀	Lethal Ct ₅₀
LED	Light Emitting Diode
MEF	Marine Expeditionary Force
MOB	Main Operating Base
MOD	Ministry of Defence
MPDS	Multipurpose Decontamination System
NAIAD	Nerve Agent Immobilised enzyme Alarm and Detector
NAPS	Nerve Agent Pretreatment Set
NATO	North Atlantic Treaty Organisation
NBC	Nuclear Biological and Chemical
NBC DPC	Nuclear Biological and Chemical Defence Policy Committee

OSAGWI	Office of the Special Assistant for Gulf War Illness
P2S	Pralidoxime Mesylate
PB	Pyridostigmine Bromide
REME	Royal Electrical and Mechanical Engineers
RGID	Reconfigured Graseby Ionics Detector
RVD	Residual Vapour Detector
SACEUR	Supreme Allied Commander Europe
SIBCA	Sampling and Identification of Biological and Chemical Agents
SICS	Ship Installed Chemical System
SNOME	Senior Naval Officer Middle East
STANAG	Standardisation Agreement
STO	Survive To Operate
TACCON	Tactical Control
TFA	Toxic Free Area
UCP	Unhardened Collective Protection
UKLF	United Kingdom Land Forces
UNSCOM	United Nations Special Commission
USMC	United States Marine Corps
VX	Nerve Agent