Emerging Issues and Case Studies in Chemical, Biological, Radiological, Nuclear and Explosive Protection

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1

INTRODUCTION

According to the 2011 European Commission CBRN Glossary [European Commission, 2011][1]:

> «CBRN is an acronym for chemical, biological, radiological, and nuclear issues that could harm the society through their accidental or deliberate release, dissemination, or impacts. The term CBRN is a replacement for the cold war term NBC (nuclear, biological, and chemical), which had replaced the previous term ABC (atomic, biological, and chemical) that was used in the fifties. "N" covers the impact by an explosion of nuclear bombs and the misuse of fissile material, "R" stands for dispersion of radioactive material e.g. by a dirty bomb.»,

and CBRNe:

> «Is an acronym which includes beside CBRN explosive substances or events.».

CBRNe materials can be weaponized (W-CBRNe) or non-weaponized (NW-CBRNe). W-CBRNe materials include weapons of mass destruction (WMD) and are intentionally used in criminal and terrorist activities. NW-CBRNe materials, also referred to as hazardous materials (HAZMAT), are linked to unintentional incidents or military operations as a secondary hazard. In both cases, serious consequences are expected for the affected population, such as intoxication, infection, irradiation, and–not least–the spread of panic.

Although the use of noxious gases has already been reported in historical times, the first large-scale use of chemical warfare agents (CWA) on the

[1] The corresponding definition in the 2022 EC CBRN Glossary [European Commission, 2022] is less comprehensive.

battlefield dates back to World War I [Garrett, 2017]: infamously known is the Second Battle of Ypres (22 April 1915) in which the Germans used chlorine gas. Despite the Chemical Weapons Convention [Organization for the Prohibition of Chemical Weapons, 1993], their use has also been reported in recent times, for example in the Syrian crisis [Postol, 2013]. In addition, CWAs are now among the arrows in terrorists' bows, as happened in the Tokyo subway [Taneda, 2005]. Spy agencies also employed them as in the poisoning of Sergei and Yulia Skripal [Vale et al., 2018].

Biological warfare agents (BWAs) are also very old, particularly in the form of throwing infected corpses inside besieged cities [Garrett, 2017]. While the Japanese military used laboratory fleas fed on plague-infected rats as biological weapons during World War II, modern wartime use of BWAs has been far less than that of CWAs [Riedel, 2004]. Fortunately, BWAs have also been banned by an international treaty, the Biological Weapons Convention [United Nations, 1972]. Nevertheless, we have recently witnessed the terrorist use of BWAs, as in the case of anthrax letters in the US [Federal Bureau of Investigation, 2023].

Nuclear and radiological threats are more recent: it was not until 1896 that Henry Becquerel accidentally discovered radioactivity, later studied in depth by Marie Skłodowska-Curie and Pierre Curie [Tretkoff, 2008]. The first and only use of nuclear bombs was that–well-known–by the US in the Japanese cities of Hiroshima and Nagasaki (6 and 8 August 1945, respectively). Although only a few states are capable of producing nuclear devices and their dissemination is limited by the Treaty on the Non-Proliferation of Nuclear Weapons [United Nations, 1968], the making of a dirty bomb or radiological dispersal device (RDD) is within the reach of terrorist groups, as evidenced by the arrest of Jose Padilla in 2002 [Fagenson, 2014].

However, terrorists' favourite threats are explosives, because of their relative ease of manufacture and high potential to create panic. Prevention involves the rapid identification of illegal bomb factories, which are used to produce improvised explosive devices (IEDs), often based on triacetone triperoxide (TATP). Therefore, the development of detection systems that can identify illegal factories where IEDs are produced proves to be of paramount importance for the safety of people and land [Fiorani et al., 2013].

As mentioned, the occurrence of serious CBRNe accidents can also be unintentional, as the following well-known cases demonstrate:

- Chemical accident: Bhopal Disaster, 1984 (about 4000 fatalities) [Broughton, 2005].
- Biological accident: Sverdlovsk Anthrax Outbreak, 1979 (about 70 fatalities) [Meselson et al., 1994].
- Radiological accident: Goiânia Accident, 1987 (4 fatalities) [International Atomic Energy Agency, 1988].
- Nuclear accident: Chernobyl Disaster, 1986 (about 30 immediate fatalities) [International Atomic Energy Agency, 2023].
- Explosive accident: Beirut Explosion, 2020 (about 210 fatalities) [Rigby et al., 2020].

The intention of this book was not to cover all the knowledge related to such a complex subject as protection against CBRNe threats. Rather, as the title indicates, the aim was to move along two axes. The first, to inform the reader about emerging issues in the field. The second, to report on hot case studies. Thus, on the problem side, we have focused on accidental chemical dispersions and nuclear/radiological incidents (Chapters 3 and 4) and, on the solution side, on recent applications of laser spectroscopy to the detection of explosives precursors and nerve agents (Chapters 5 and 6).

Emerging issues will be noted by the attentive reader in the text's watermark, particularly in Chapters 2, 3 and 4. The subject matter is so complex and the actors so varied that new professional figures and updated training tools are emerging (Chapter 2). Response structures, having to cope with events of exceptional scope in terms of geographical and temporal extension, have a level of complexity and interrelationships that must be deeply understood as they unfold during the response phase (Chapter 3). Investigation and communication are becoming more and more important (Chapter 4). Forensic investigation requires increasingly sophisticated technical and scientific equipment and detective skills. Effective communication, in a world where information is transmitted at previously unimaginable speeds, is essential to prevent panic reactions from causing damage comparable to, if not greater than, the adverse event itself.

With this type of discussion, we believe we have offered an up-to-date treatment of emerging operational, tactical, and strategic aspects of the subject. We are confident that by the end of the book, thanks to the didactic and pragmatic approach that has been chosen, favouring realistic

cases over a lengthy systematic treatment, the expert will have been informed of some current trends and techniques, and the novice will have a sufficiently accurate and comprehensive first knowledge of protection against CBRNe threats.

2

ACTORS IN CBRNE PROTECTION: DIFFERENCE OF ROLES AND IMPORTANCE OF TABLE-TOP EXERCISES

2.1 Abstract

All developed nations have management structures to respond promptly to chemical, biological, radiological, nuclear, and explosive (CBRNe) threats. The role of two expert figures is critical in these structures: first responders, who must act immediately on the spot, and advisors to decision-makers, that provide the structure manager with the information they need to take action, develop pre-incident strategies, and formalize lessons learned post-incident. Incident simulation exercises allow a quite lifelike mimicking of a CBRNe emergency and are helpful for training personnel, testing cooperation, and validating plans. In particular, table-top exercises provide coaching for decision-making, incorporate all aspects of the scenario, allow for changes in the skills of the staff involved, are adjustable (e.g. location and time), and are significantly cheaper than operations-based exercises.

2.2 CBRNe first responders, CBRNe advisors to decision-makers, and their difference

CBRNe defence includes context study, prevention, threat analysis, preparedness, awareness (warning, alerting, reporting), response (passive protection, mitigation, contamination avoidance), and recovery (decontamination, remediation, lesson learned) all aspects that require knowledge and management to reduce casualties and fatalities. In practice, the phases of managing a CBRNe incident can be outlined as follows:

1. Prevention: what can I do to prevent the accident from happening? This includes context study: e.g., are extremist groups active in the region?
2. Preparedness: is there a structure of individuals and teams prepared, coordinated, and equipped to deal with the threat? This includes threat analysis, remembering that risk is roughly proportional to the product of threat and exposure, both appropriately quantified.
3. Incident itself.
4. Response:
   a. Early response: e.g., first medical care. This includes awareness.
   b. Statement that the incident is CBRNe.
   c. Expert response: e.g., use of personal protective equipment (PPE) appropriate to a specific biological warfare agent (BWA).
5. Recovery:
   a. Early recovery: e.g., decontamination of a subway station after a biological warfare agent (CWA) release.
   b. Long-term recovery: e.g., remediation of a large area after an industrial disaster.
   c. Lessons learned from what happened: e.g., how can we improve our response plans by reflecting on what occurred in a real incident?

The term “CBRNe first responders” refers to individuals and teams involved in activities that address the immediate and short-term effects of a CBRNe incident. These are military, police, fire brigades, health services, and hazardous materials (HAZMAT) teams acting to mitigate the effects of a CBRNe incident by managing the scene, people, and information.

The term “CBRNe advisors to decision-makers” refers to experts who provide decision-makers with all important information about the CBRNe incident. The information must be objective and supported by evidence. The advisor must know all alternative strategies for responding to the incident and recommend the best one.

First responders are involved mainly in phases 2, 3, and 4, while advisors to decision-makers are most active during phases 1, 2, 4.b, 4.c, and 5. CBRNe incident declaration is one of their main responsibilities. A cross-cutting skill that will need to be practiced during the incident is

communication with the media: information should be brief, adhere to the facts, and not generate an unnecessary alarm.

Only the essentials have been provided here. CBRNe issues are complex and can be viewed from many perspectives. For example, the figures below illustrate the phases of managing a CBRNe incident from a medical and military viewpoint and are particularly instructive because they illustrate the role of first responders (e.g., they are particularly involved in "Response & Incident Management" on Fig. 2.1 and "Medical Support" on Fig 2.2) and the role of advisors to decision-makers (e.g., they are particularly involved in "Basic & Clinical Sciences" on Fig. 2.1 and "Scientific & Technical Collaboration" on Fig. 2.2).

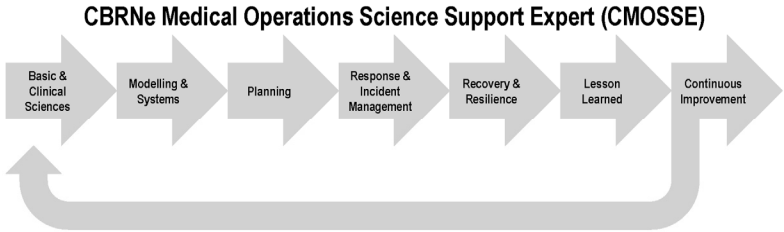

Fig. 2.1. Core elements of CBRNe science, overseen by the CBRNe Medical Operations Science Support Expert [Coleman et al., 2019].

Fig. 2.2. NATO's principles and commitments for CBRN defence [NATO, 2022].

Also, note the rough correspondence between the figures and the phases above. On Fig. 2.1, phases 1 and 2 correspond to arrows from "Basic & Clinical Sciences" to "Planning," phases 3 and 4 to "Response & Incident Management," and phase 5 to the remaining arrows. On Fig. 2.2, we note that NATO prefers to merge phases 2 through 4 into the "PROTECT" NATO's "core function" (the core functions are the words in the dark grey background), although it is true that all the NATO's "strategic enablers" (the strategic enablers are the expressions in the light grey crown) have relevance to the above phases (e.g., "Capacity Building" is related to phase 5.c).

CBRNe event management structures can also be extremely complex. As an example, we give in the figure below the governance of the Strategy and Action Plan extracted from the Chemical, Biological, Radiological, Nuclear and Explosives Resilience Strategy for Canada [Government of Canada, 2011].

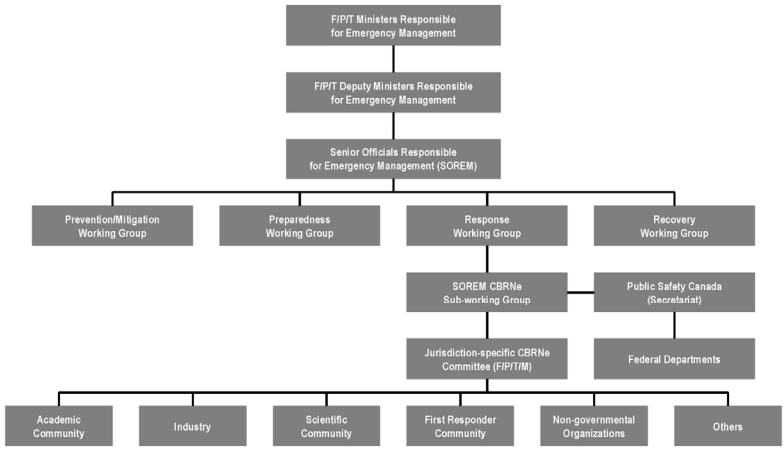

Fig. 2.3. Block diagram illustrating the relationship between the various bodies that provide governance to the Strategy and Action Plan of the Chemical, Biological, Radiological, Nuclear and Explosives Resilience Strategy for Canada. It depicts the different levels of emergency management, from the federal, provincial, and territorial ministers responsible for emergency management, to the many stakeholders contributing to CBRNe resilience in Canada. F/P/T/M stands for Federal, Provincial, Territorial, Municipal [Government of Canada, 2011].

We observe that first responders are clearly identified with a box (first responder community). Similarly, decision-makers could correspond to senior officials responsible for emergency management (SOREM). The position of advisors to decision-makers appears less clearly pinpointed and could be that of working groups (the sub-working group included), although the presence of advisors to decision-makers cannot be excluded in the academic community, industry, scientific community, and non-governmental organizations.

The role of first responders and advisors to decision-makers is outlined in some reference documents. For example, NATO's Guidelines for First Responders to a CBRN Incident [NATO, 2014a]–basically NATO's civil emergency planning–assigns well-defined tasks to first responders:

1. Information gathering, assessment and dissemination,
2. Scene management,
3. Saving and protecting life,

and states that after early response:

> «specialist advice should be sought to assist in consequence management»

and

> «specialist advice and resources may also be sought as part of the recovery management phase, including … return to normality»,

thus sketching the function of advisors to decision-makers, at least in the aftermath of the incident.

The US National Fire Protection Association's approach is slightly different [National Fire Protection Association, 2018]. Three professional figures with roles having increasing complexity are identified, as per the table below: while the first two figures roughly correspond to first responders, the last one has some tasks that might generally be assigned to advisors to decision-makers.

Figure	Description
Awareness level responder	Recognize the presence of HAZMAT/weapons of mass destruction (WMD), protect themselves, call trained personnel, and secure the area.
Operation level responder	Responds to HAZMAT/WMD incidents for the purpose of protecting nearby persons, the environment, or property from the effects of release
Hazardous Material Technician	Responds to HAZMAT/WMD incidents using a risk-based response process to analyse a problem involving HAZMAT/WMD, plan a response to the problem, implement the planned response, evaluate progress of the planned response and adjust as needed, and assist in terminating the incident

Table 2.1. Professional figures involved in CBRNe protection according to the US National Fire Protection Association [National Fire Protection Association, 2018].

Level	Function	Task	Level	Function	Task
Basic	Prevent	Prevent acquisition/supply Deter CBRN use Support WMD non-proliferation	Specialized	Prevent	CBRN threat analysis CBRN sensitive site reconnaissance
	Recover	Mitigate effects of CBRN incident		Recover	Consequence management
	Prevent & protect	Reduce offensive CBRN capability Prevent attacks		Prevent & protect	Hazard assessment CBRN risk management Warning & reporting
	Protect & recover	–		Protect & recover	Hazard management Physical protection
	Prevent & protect & recover	Disrupt CBRN activities CBRN render safe		Prevent & protect & recover	CBRN detection, identification, and monitoring (DIM) Information management Medical countermeasure

Table 2.2. Tasks assigned to NATO's basic and specialized defence levels [NATO, 2014b].

Specialist CBRN Defence Capabilities [NATO, 2014b]–basically NATO's military emergency planning–has an even different approach. Three defence levels are planned: (1) basic, (2) enhanced, and (3) specialized. All involve the three NATO's core functions (prevent, protect, and recover), and again, while the first level roughly corresponds to first responders, the last one has some tasks that might generally be assigned to advisors to decision-makers, as shown in Table 2.2.

2.3 Table-top exercises and their importance

Managing a CBRNe incident is an extremely difficult task for at least three reasons:

1. It requires highly specialized skills.
2. It involves the management of scenes, people, and information.
3. It entails the need to have large numbers of people and teams with clear and distinct roles that must operate together quickly and in a coordinated manner.

Related to this last point, incident simulation exercises can be extremely useful because they acquaint trainees with current plans, policies, and procedures thus allowing the various actors to play their respective roles in harmony with each other, highlighting any critical issues in operation, communication, and chain of command, before the incident occurs, being able to reason about how the emergency response works outside of stressful conditions and having time to make appropriate corrective actions.

For this reason, incident simulation exercises have been successful in many areas: e.g., public health emergencies [World Health Organization, 2023a], severe weather [READY, 2023], and tsunamis [United Nations Educational, Scientific and Cultural Organization, 2023]. In the US, the Federal Emergency Management Agency (body of the Department of Homeland Security) has developed the Homeland Security Exercise Evaluation Program (HSEEP) [Department of Homeland Security, 2020]. According to HSEEP, there are two types of exercises:

1. Discussion-based exercises: seminars, workshops, table-top exercises (TTX), and games, in order of complexity.

2. Operation-based exercises: drills, functional exercises (FE), and full-scale exercises (FSE), in order of complexity.

Usually, operation-based exercises are more challenging and complicated than discussion-based exercises and are implemented later. Table 2.3 briefly describes the above exercises. In addition, we summarise in Table 2.4 the elements of a TTX according to HSEEP because they provide an accurate description of such an exercise.

The roles in a TTX can be a wide variety (fire chief, local health department, environmental agency...), but–in general–there must be an incident commander on whom the TTX team leader and the spokesperson depend. We note that some aspects of TTX seem particularly useful for first responders (enhance general awareness, enhance roles and responsibility understanding, etc.) and others for advisors to decision-makers (recommended revisions to current plans, policies, and procedures; AAR/IP, etc.).

Exercise	Description
Seminar	Exercise that orients participants to or provides an overview of authorities, strategies, plans, policies, procedures, protocols, resources, concepts, and ideas.
Workshop	Exercise often employed to develop policy, plans, or procedures.
TTX	Exercise in response to a scenario, intended to generate a dialogue of various issues to facilitate a conceptual understanding, identify strengths and areas for improvement, and/or achieve changes in perceptions about plans, policies, or procedures.
Game	Exercise that is a structured form of play designed for individuals or teams in a competitive or noncompetitive environment. It is an event players take part in and are guided by clear rules, data, and procedures for its execution.
Drill	Exercise often employed to validate a single operation or function.
FE	Exercise designed to test and evaluate capabilities and functions while in a realistic, real-time environment; however, movement of resources is usually simulated.
FSE	Exercise that is typically the most complex and resource-intensive of the exercise types and often involves multiple agencies, jurisdictions/organizations, and real-time movement of resources.

Table 2.3. Elements of a TTX according to HSEEP [Department of Homeland Security, 2020].

The conduct of a TTX is led by a facilitator and generally begins by dividing participants into teams and assigning them roles. Then, maps and icons are reviewed and the scene is set. Important parts of the exercise are the injects in which a situation is described to which the teams must respond by accomplishing a task: for each inject, the first responders can be asked what action to take and the advisors to decision-makers what option to suggest to the decision-makers. The answer can be "none" in either case. Teams can submit requests for information (RFI) to the facilitator.

Purpose	▪ Generate discussion of various issues regarding an exercise scenario ▪ Facilitate conceptual understanding, identify strengths and areas for improvement, and/or achieve changes in perceptions
Structure	▪ Scenario is presented to describe an event at a simulated time ▪ Players apply their knowledge and skills to a list of problems presented by the facilitator ▪ Problems are discussed as a group, and resolution may be reached and documented for later analysis ▪ Plenary or breakout session(s) ▪ Discussion led by a facilitator(s) ▪ Presentation
Participant goals	▪ Enhance general awareness ▪ Enhance roles and responsibility understanding ▪ Validate plans and procedures ▪ Discuss concepts and/or assess types of systems in a defined incident
Conduct characteristics	▪ Requires an experienced facilitator ▪ In-depth discussion ▪ Problem-solving environment ▪ All participants should be encouraged to contribute to the discussion and be reminded that they are making decisions in a no-fault environment
Outcomes	▪ Recommended revisions to current plans, policies, and procedures ▪ An After-Action Report (AAR)/Improvement Plan (IP)

Table 2.4. Elements of a TTX according to HSEEP [Department of Homeland Security, 2020].

The actual TTX play requires active participation, respect for the idea of others, openness to new ideas and creative solutions, while remaining realistic, and ends with the hot wash, a phase in which the progress of the exercise is reviewed.

Throughout the TTX, it will be necessary for the spokesperson to manage the relationship with the media–probably already on site with reporters and photographers–through a first statement and some follow-up statements. The first statement will inform what, where, and when, specifying whether or not the incident is CBRNe, and concluding with actions taken. The follow-up statements, released regularly, should facilitate media cooperation and anticipate uncontrolled leaks of inaccurate information, also spread by informal means, e.g., social networks (regarding their role in CBRNe emergencies, see also the recent Handbook to Combat CBRN Disinformation [United Nations Interregional Crime and Justice Research Institute, 2022]).

For a TTX to be successful, participants will need to identify with it as if it were real, both by playing their role, being guided by the facilitator, and without criticizing the scenario. Participants are expected to work as a team, proposing solutions based on prior experiences and assigned roles, and not to know everything in their field.

To sum up, TTX is important because:

1. It enables the validation of plans, policies, and procedures.
2. It detects problems and deploys solutions.
3. It highlights long-term measures that need to be pursued.
4. It reviews the roles, responsibilities, and activities of the parties involved in incident response.
5. It reinforces their communication, cooperation, and coordination.

Moreover, TTX has some relevant advantages:

1. It enables training in decision-making.
2. It includes all aspects of the scenario of interest.
3. It allows for a change in the skills of the personnel involved.
4. It can be readily customized: its place of occurrence can be freely chosen, and its time course can be adapted to needs.

5. While allowing a reasonably close-to-reality simulation of a CBRNe incident, it is considerably cheaper than operation-based exercises.

In addition to offering a cost-effective, low-risk, and highly efficient manner to evaluate emergency response plans before they are required, well-conceived TTXs help personnel in the organization gain a better understanding of their role in an emergency by creating a secure environment to think critically about potential contingencies that could affect regular operations.

For decision-makers and group leaders, TTXs also ensure confidence that key individuals and teams are properly instructed and prepared for emergencies, which can dramatically improve the speed of response, possibly saving lives and safeguarding against extensive property damage.

2.4 Conclusions

CBRNe threats are emerging global problems. E.g., the use of large-scale chemical weapons dates back to the beginning of the last century and has not been totally averted by the Chemical Weapons Convention. In addition, terrorist groups attempt–with alternating success–to develop weapons of mass destruction. Finally, some civilian activities have also resulted in severe CBRNe incidents.

For this reason, all advanced countries have equipped themselves with facilities capable of responding to the deployment of CBRNe threats. These are complex organizations involving various actors that must act in a prepared, rapid, and coordinated manner. In this context, the role of two expert figures is key: first responders who must act promptly in the field and advisors to decision-makers who are called precisely to provide decision-makers with the necessary information both to direct actions, to develop strategies before the incident, and to formalize lessons learned after the incident.

We note that in reading the standard documents of the major agencies, it appears that the role of first responders, despite the inevitable differences from one agency to another, is more staggered than that of advisors to decision-makers.

The complexity in the management of a CBRNe incident amply justifies the use of response training exercises by the various actors

involved, with particular reference to learning both the execution of the tasks assigned and the coordinated and efficient operation of different professional skills.

For this reason, a whole variety of CBRNe incident simulation exercises have been developed, both discussion-based (seminars, workshops, table-top exercises, and games) and operation-based (drills, functional exercises, and full-scale exercises). In this regard, table-top exercises allow a fairly near-real simulation of a CBRNe incident and are advantageous for a whole range of reasons: they provide coaching for decision-making, incorporate all aspects of the scenario in question, enable modifications in the capabilities of the engaged staff, can be tailored (e.g., changing location and time), and are significantly more cost-effective than operations-based exercises.

3

ACTIONS IN RESPONSE TO THE DISPERSION OF A HAZMAT IN A MAJOR CITY

3.1 Abstract

The UK was chosen as a paradigm for this study because, like most developed countries, it has management structures in place to respond rapidly to chemical, biological, radiological, nuclear, and explosive (CBRNe) threats. In these structures, the role of two experts is crucial: first responders who must act immediately on the ground, and CBRNe advisors to decision-makers who provide the structure manager with the information they need for emergency response. After illustrating a potential fictitious Toxic Industrial Chemical (TIC) dispersion in central London, this chapter describes facing of the event, casualty reduction, and recovery to normality, with particular emphasis on the role of CBRNe advisors in supporting decision-makers.

3.2 Facing the event

The accidental release and uncontrolled dispersion of a TIC–also known as hazardous material (HAZMAT)–is a classic case study of a CBRNe event because unfortunately many such incidents have occurred in the past, e.g.:

- Seveso accident, 1976, hundreds chloracne cases, decreased fertility, and increased risk of cancer and cardiometabolic outcomes [Eskenazi et al., 2018].
- Bhopal disaster, 1984, nearly 4,000 dead and almost 600,000 injured [Broughton, 2005].
- Graniteville train crash, 2005, 9 dead and about 250 injured [Dunning & Oswalt, 2007].

The terms “CBRNe first responders” and “CBRNe advisors to decision-makers” (hereinafter simply “CBRNe advisors”) were introduced in the previous chapter. After a short description of the incident itself, here we will focus on the response and recovery phases from the perspective of a CBRNe advisor.

SBAF Metals Limited is a metals manufacturing company located in Bishopsgate, London EC2N 4AY, in the Spitalfields district in the East End of London, within the London Borough of Tower Hamlets. Tower Hamlets has a population of 310,000 and an area of 18 km^2. On 22 May 2023, at 10:37 a.m., there is a leak of chlorine, which is known to be a gas used in metal production [Xing et al., 2020][1].

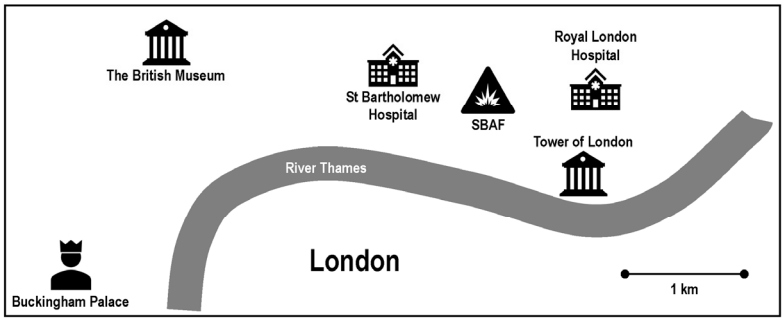

Fig. 3.1. Area of emergency. Note Royal London Hospital, St Bartholomew Hospital and Buckingham Palace.

At 10:48 a.m., the leak is fixed by SBAF operators with personal protective equipment (PPE). At 10:52 a.m., SBAF inform the police about time, location, and type of incident, and explains that: the main building of the production area is affected; five factory workers have symptoms of

[1] Such an accident is not impossible. On 16 November 2016, two workers were hospitalised following a chlorine leak at the Canexus Chemical Plant in North Vancouver (in 2011, four people were taken to hospital after a similar leak at the same plant) [Judd, 2016]. On 23 March 2022, a large amount of chlorine gas was released in the aquatic centre of the London Olympic Park (29 injured taken to hospital, 48 patients treated on site and about 200 people evacuated) [Weaver, 2022]. Furthermore, a quick search for the expression “chemical plant” in Google Maps returns a dozen results in the city of London.

intoxication and are being treated in the infirmary by the competent doctor; traffic in the area seems smooth; and initial estimates indicate that, although the leak has been fixed, the contaminated area could extend over a radius of 2 km, thus covering an area of 12.56 km2, in which more than 200,000 inhabitants live.

At this point, in order to understand how a CBRNe advisor can help to face the event, it is important to understand the UK's legal and institutional framework dealing with CBRN crises. The Civil Contingencies Act 2004 (CCA) [UK Government, 2004] is the primary piece of legislation guiding how the UK responds to emergencies, including CBRNe crises [Bonfanti et al., 2014]. According to CCA there are three types of emergencies. Our event corresponds to emergency (1) (a):

> «an event or situation which threatens serious damage to human welfare in a place in the United Kingdom»

because it may cause:

> «(a) loss of human life, (b) human illness or injury, (c) homelessness, (d) damage to property,»

and disruption of supplies (e), systems (f), facilities (g), and services (h).

According to the UK's Concept of Operations (CONOPs) [UK Government, 2013], the three phases of emergency management– preparation, response, and recovery–should be inspired by the following principles:

> «i. Preparedness: All individuals and organisations that might have to respond to emergencies should be properly prepared […] ii. Continuity: The response to emergencies should be grounded within organisations' existing functions […] iii. Subsidiarity: Decisions should be taken at the lowest appropriate level, with co-ordination at the highest necessary level […] iv. Direction: Clarity of purpose should be delivered through an awareness of the strategic aims and supporting objectives for the response […] v. Integration: Effective co-ordination should be exercised between and within organisations and local, regional and national tiers of a response […] vi. Communication: Good two-way communications are critical to an effective response […] vii. Co-operation: Positive engagement based on mutual trust and understanding […] viii. Anticipation: In order to anticipate and manage the consequences of all kinds of emergencies,

planners need to identify risks and develop an understanding of both the direct and indirect consequences in advance where possible.».

CONOPs defines three level of emergencies: significant (1), serious (2), and catastrophic (3). Our event corresponds at least to level 2 that involves the central government response coordinated by a Cabinet Office Briefing Room (COBR) under the leadership of a Lead Government Department (LGD): e.g., in our event, the LGD could be the Home Office.

CCA classifies responders into two categories: "Category 1 responders"–such as the emergency services, local authorities, and National Health Service (NHS) bodies–are organisations that are at the heart of the response. Among the "Category 1 responders", the police have a key role: they are the first responders called upon to intervene, provide a 24/7 operational support centre that mobilises CBRNe specialists, liaise with the scientific and technical advice, and–more importantly–coordinate the overall response of the emergency services from the event to the early return to normality. "Category 2 responders" are cooperating bodies and include the Health and Safety Executive, transport companies and public utilities.

COBR and the principal tiers of Integrated Emergency Management (IEM) during major emergencies are illustrated in Fig. 3.2 and 3.3, respectively. CBRNe advisors play a key role in the COBR (boxes below) and make important contributions at the strategic and tactical level (SCG and TCG), somewhere between decision-makers (COBR, LGD, and RED), and first responders (OCG).

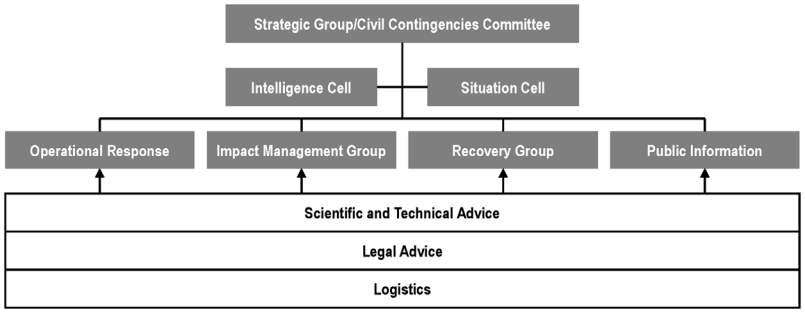

Fig. 3.2. Structure of COBR [UK Government, 2013].

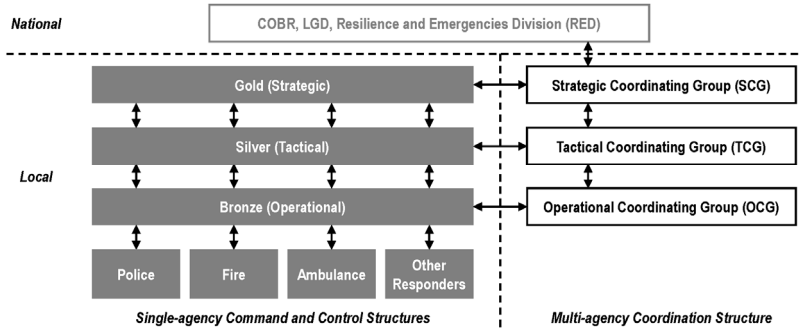

Fig. 3.3. Tiers of IEM [Deeming & Otley, 2018].

In London in particular, there is the London Emergency Services Liaison Panel (LESLP). It was set up in 1973 and is made up of representatives from the following agencies: Metropolitan Police Service, London Fire Brigade, City of London Police, British Transport Police, London Ambulance Service, Coastguard, Port of London Authority, Military, Transport for London, London Resilience Group, and all London local authorities.

Although the statement that the incident was CBRNe is usually made by a CBRNe advisor, when the police received the call from SBAF, they immediately understood that a major CBRNe incident had occurred due to the size of the leak and the danger of chlorine, a known chemical agent (CA). However, as we have mentioned, the police can activate CBRNe advisors at any time to state that the incident was CBRNe. According to Bonfanti et al. [2014]:

> «The police force deploys advisors and liaison officers to police commanders in the area of the event and also cooperates with specialist military and scientific assets on scene. Moreover, the police force acts as an interface with Government-level specialists to ensure that advice is consistent at all levels of command.».

Once it is clear that a major incident has occurred, in accordance with the Joint Emergency Services Interoperability Principles (JESIP) [Hall et al., 2021], the police operator will request maximum information from the BASF interlocutor using the ETHANE approach, obtaining the information provided above regarding our incident:

- **E**xact location: The exact location of the incident.
- **T**ype: The type of incident, including how many vehicles, buildings, etc. are involved.
- **H**azards: Both current and potential.
- **A**ccess: The best route for the emergency services to reach the site, or obstacles and bottlenecks to avoid.
- **N**umbers: Number of casualties, dead and injured on site.
- **E**mergency services: What services are already on site and what others are needed.

At this point, the incident management structure described above is set in motion by the police: three intervention zones are defined, and first responders are deployed in the zones as in the figure (only police HAZMAT teams will enter the hot zone). In defining the intervention zones, the police make use of CBRNe advisors who–in contact with SBAF staff–try to figure out the scale of the leak from technical data such as pipe flow rate, gas pressure, crack size etc. In the meantime, other CBRNe advisors are trying to better define the intervention zones based on the area of CA plume propagation obtained from weather data such as wind speed/direction and rain intensity (wet deposition of the CA). The definition of the three zones includes the establishment of traffic cordons/deviations, ambulance/evacuation routes, and zone access control points, including a crowd control line at the cold zone boundary[2]. The hot zone extends far enough to avoid primary contamination. The warm zone is where victims, HAZMAT team members and equipment are decontaminated in a specially prepared access corridor (against the wind). This is also where life-saving operations take place. The cold zone is the location of the incident commander and local patient treatment. The

[2] All the assessments of CBRNe advisors mentioned in this paragraph can be supported by specific software such as, e.g., UrbanAware (https://www.riskaware.co.uk/what-we-do/urbanaware/) which includes Urban Dispersion Modelling (with building profiles and HAZMAT penetration), Atmospheric Dispersion Modelling (with prevailing weather conditions), Geographical and Environmental Database Information System, Urban Sub System (with amount of substance stored/handled and population estimates), a Sensor Placement Tool and Source Term Estimation, and can track hazards, forecast plume, design cordons, estimate casualties, predict damage, and geolocate/inform first responders by smartphone.

CBRNe advisor prescribes level A PPE inside the factory, level B in the hot zone, Level C in the warm zone.

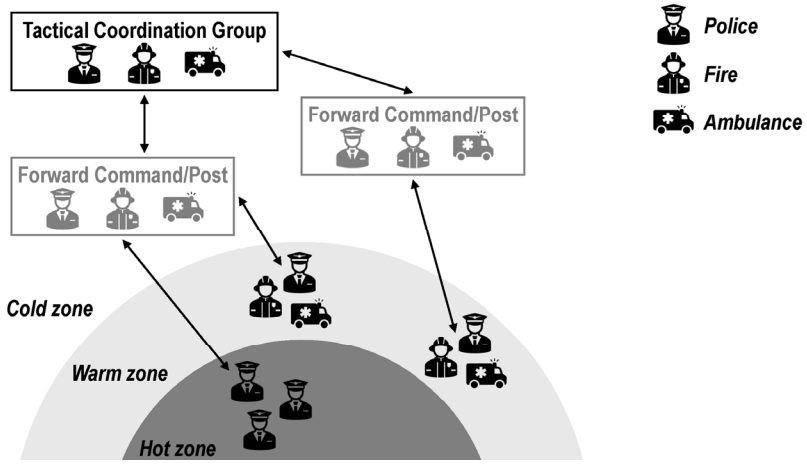

Fig. 3.4. Intervention zones (adapted from Kerslake [2018]).

Royal London Hospital and St Bartholomew Hospital, the two largest hospitals in the area (about 1 km from the SBAF plant, see map in Fig. 3.1), are informed that they may treat chlorine patients. The police are ready to implement the evacuation plan for the highest offices of the state. The Royal Air Force is also alerted, and a helicopter is immediately dispatched to Buckingham Palace for a possible evacuation of His Majesty Charles III and the royal family, even though the SBAF plant is about 4.5 km away as the crow flies (see map).

The top priority for first responders is scene isolation: they control access to and from the incident scene, and the movement of contaminated victims. They also carry out primary triage, primary decontamination, secondary triage, medical care, and transport.

Once on site, they should also gather as much information as possible about the people involved in the incident and facilitate a quick and safe evacuation of the factory: how many workers are there? Are they trained for emergencies? Do they have enough adequate PPE?

In the meantime, it is now crucial to inform the population without generating excessive alarmism. With the help of CBRNe advisors, a media and communication strategy is quickly put in place that obeys a principle established by CONOPs:

> «Reliable information must be passed correctly and without delay between those who need to know, including the public.».

Radio, television, social media and the recently experimented sending of emergency alerts to all mobile phones and tablets [Morgan, 2023] are used for this purpose. Contact with the media can be delegated to a state or local health department: hospitals, with the assistance of the health department, must prepare a statement outlining the number of victims, their symptoms, and where to obtain further information.

People should be invited to follow the “Remove-Remove-Remove” guidance issued by the UK National Counter Terrorism Security Office (NaCTSO) [National Counter Terrorism Security Office, 2021].

In particular, together with precise information on the affected area, the CBRNe advisor suggests that the following instructions should be given in the event of our emergency:

- Remove yourself: Move indoors and take cover. Make sure windows are closed and ventilation systems are turned off to ensure that the contamination does not get inside. If you cannot go indoors, leave the area where the chlorine has been released. If you cannot leave the area, get to the highest ground possible, as chlorine is heavier than air. If you are in a car, close the windows and air conditioning and leave the area. If you are in a subway, continue travelling until you leave the area.
- Remove outer clothing: If you have been exposed to chlorine, remove all layers of clothing (including jewellery and accessories) and shower as soon as possible. Avoid pulling clothing over your head. If you must pull clothing over your head, close your eyes and mouth and hold your breath to avoid getting chlorine in your eyes, nose or mouth. Put items in a plastic bag. If you wear contact lenses, put them in the bag.
- Remove the substance: Wash from head to toe with plenty of lukewarm water and mild soap for several minutes. Finish by rinsing with clear water. Try to avoid getting water in your eyes, nose, or mouth. Do not scrub. If your eyes burn or you can’t see normally, rinse your eyes with lukewarm water for a quarter of an hour. Do not use eye drops. Dry your face, then tilt your head back and dry your hair, then dry your body.