[PRACTICE]

D2.1 Scenario template, existing CBRN scenarios and historical incidents

PRACTICE WP2 deliverable

Dissemination level: Public

Nature: Report

SEVENTH FRAMEWORK PROGRAMME

Preparedness and Resilience Against CBRN Terrorism using Integrated Concepts and Equipment

practice.fp7security.eu

Title:	D2.1 Scenario template, existing CBRN scenarios and historical incidents	
Date:	November 15, 2011	
Authors:	Monica Endregard, Hanne Breivik, Hege Schultz Heireng, Elin Enger, Therese Sandrup	Norwegian Defence Research Establishment (FFI)
	Dominic Kelly	CBRNE Ltd
Print:	ISBN 978-82-464-1985-5	
Electronic:	ISBN 978-82-464-1986-2	

This project has received funding from the European Community's Seventh Framework Programme. The views expressed in this document are purely those of the writer and may not in any circumstances be regarded as stating an official position of the European Community.

Summary Work Package 2

The overall aim of the project "Preparedness and Resilience Against CBRN Terrorism using Integrated Concepts and Equipment" (PRACTICE) is to improve the ability to respond to and recover from a Chemical (C), Biological (B), Radiological (R) or Nuclear (N) incident. The objective of the project is to create an integrated European approach to a CBRN crisis – *i.e.* a European Integrated CBRN Response System. This will be achieved through the development of an improved system of tools, methods and procedures that is going to provide EU with a capability to carry out a truly integrated and coordinated operational reaction following the occurrence of a CBRN crisis, whether it is caused by a terrorist act or an accident.

The objective of the work package (WP) 2 on selection of scenarios and identification of critical event parameters is to:

- Produce a template for scenarios and requirements, as a basis to make a selection of appropriate and representative CBRN-scenarios.
- Based on the selected scenarios and experience from exercises, real events and experience from earlier relevant projects, identify, describe and organize sets of critical event parameters/observables characterizing the events, which first responders and authorities use as input for selecting, prioritising and in a number of cases developing appropriate emergency preparedness and response measures.
- Identify a set of non-terrorist accident scenarios, which will be used as reference to sort out CBRN-specific parameters/observables and as an aid to the gap analysis to be carried out in WP4.
- To create – as part of a CBRN response toolbox and training kit to be developed in WP4, WP5, WP6 and WP7 – a set of publicly available CBRN scenarios (not classified) that can be used by the European countries for emergency preparedness planning, education, training, and exercises. Such a set of publicly available scenarios is not available today.

WP2 is divided in three tasks with associated deliverables:

- Task 2.1. Scenario template and requirements
    - Deliverable D2.1 (a) Detailed scenario template and requirements for consequence assessments and (b) collection of submitted scenarios (those publicly available) and information on accidents
- Task 2.2. Reference set of scenarios
    - Deliverable D2.2 Reference set of CBRN scenarios covering releases of hazardous chemical (C), biological (B) and radiological (R) substances
- Task 2.3. Consequence assessments and identification of critical event parameters
    - Deliverable D2.3 Consequence assessments of the selected set of reference CBRN scenarios and critical event parameters

This report, "D2.1 Scenario template, existing CBRN scenarios and historical incidents", constitutes the first deliverable of WP2 "Scenarios and critical event parameters" of the EU FP7 project PRACTICE. This WP is lead by the Norwegian Defence Research Establishment (FFI).

The research leading to the results of PRACTICE has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 261728.

Contents

1. Executive Summary

This report, “D2.1 Scenario template, existing CBRN scenarios and historical incidents”, constitutes the first deliverable of Work Package (WP) 2 “Scenarios and critical event parameters” of the EU FP7 project “Preparedness and Resilience Against CBRN Terrorism using Integrated Concepts and Equipment” (PRACTICE). This WP is lead by the Norwegian Defence Research Establishment (FFI). This report contains:

- An overview of CBRN scenarios used in previous projects
- Examples of historical cases of CBRN terrorism and accidents
- A scenario template for the reference set of CBRN scenarios in PRACTICE
- Requirements for consequence assessments and subsequent use in other WPs

The work has been based on background information and active discussion and revisions among the following WP2 participants:

Ingrid Bastings	Netherlands Organisation for Applied Research (TNO)
Hanne Breivik	Norwegian Defence Research Establishment (FFI)
Stéphanie Damiot	EADS- Cassidian S.A.S
Monica Endregard	FFI
Elin Enger	FFI
Håkan Eriksson	Swedish Defence Research Agency (FOI)
Lionel Expert	EADS- Cassidian S.A.S
Pierre-Alain Fonteyne	Université catholique de Louvain
Hege Schultz Heireng	FFI
Dominic Kelly	CBRNE Ltd
Kristi Mo	FFI
Lena Norlander	FOI
Dzenan Sahovic	University of Umeå
Therese Sandrup	FFI
Marcin Smolarkiewicz	Main School of Fire Service (SGSP)
John Aa Tørnes	FFI
Nathalie Vink	TNO
Tomasz Zweglinski	Main School of Fire Service (SGSP)

We thank the June 2011 workshop participants Ola Nerf (Södersjukehuset, Sweden), Dianne van Hemert (TNO, The Netherlands), Helge Opdahl (Oslo University Hospital, Norway) and Brooke Rogers (King’s College London, UK) for their valuable inputs.

The report was written by representatives from FFI and CBRNE Ltd and revised by the above WP2 participants.

2. Introduction

WP2 is responsible for identifying, describing and organising sets of critical event parameters or observables characterising various types of CBRN events. Critical parameters can be something that is observed which makes stakeholders conclude that an incident is a CBRN incident. Other critical parameters might be technological parameters such as temperature, wind direction and concentration of a threat agent. Human related medical or psychological factors as well as parameters related to intelligence should also be included. The work will be carried out through collaboration with first responders and authorities, using a selection of scenarios and experience from exercises, real events and earlier relevant projects. A set of reference scenarios will be established to enable this project to identify emergency preparedness and response measures and operational functions in all phases of a CBRN crisis. The identified parameters and scenarios will prepare the ground for the development and testing of the PRACTICE toolbox that is carried out in all of the succeeding work packages. WP2 is divided in three tasks with associated deliverables:

- Task 2.1. Scenario template and requirements
    - Deliverable D2.1 (a) Detailed scenario template and requirements for consequence assessments and (b) collection of submitted scenarios (those publicly available) and information on accidents
- Task 2.2. Reference set of scenarios
    - Deliverable D2.2 Reference set of CBRN scenarios covering releases of hazardous chemical (C), biological (B) and radiological (R) substances
- Task 2.3. Consequence assessments and identification of critical event parameters
    - Deliverable D2.3 Consequence assessments of the selected set of reference CBRN scenarios and critical event parameters

This report constitutes the first deliverable of WP2 and contains:

- An overview of CBRN scenarios used in previous projects
- Examples of historical cases of CBRN terrorism and accidents
- A scenario template for the reference set of CBRN scenarios
- Requirements for consequence assessments and subsequent use in other WPs

3. Objectives and definitions

3.1 Objectives and method of work

The aim of Task 2.1 of WP2 is to define the framework and requirements for CBRN scenario descriptions and the level of detail needed to ensure compatibility with subsequent use in PRACTICE WPs. In addition, this task aims to collect information on existing relevant work and CBRN scenarios in order to avoid duplication of work. PRACTICE participants have shared information on existing templates, worked-through scenarios and consequence assessments, both historical events and hypothetical scenarios, and previous results. This background information has been used as a basis for this report and will be used as a basis for selection and development of the set of reference CBRN scenarios. Active involvement from WP leaders, stakeholders and end-users was also achieved through a workshop held at FFI 22 June 2011. The participants shared background information and presented and discussed expectations and requirements for the reference set of CBRN scenarios. This formed the basis for development and agreement on the scenario template.

Chapter 4 gives an overview of CBRN scenarios developed and used in previous projects. Chapter 5 provides summaries of some important historical cases of CBRN terrorism. Chapter 6 gives short summaries of some historical CBRN accidents. Chapter 7 presents the agreed upon template and the requirements for the PRACTICE set of scenarios. Chapter 8 outlines conclusions and further work in WP2.

3.2 Definitions and delimitations

This chapter provides definitions of key terms used in this report and WP2 as a whole and specifies important delimitations.

For the purpose of this project, Chemical (C), Biological (B), Radiological (R) or Nuclear (N) incidents encompass all events in which exposure to C, B, or R threat compounds cause great harm to the health of people, animals and/or the environment, as well as incidents in which nuclear materials undergoing fission cause harm through dispersed radioactive fission products or by direct irradiation. CBRN incidents may be caused by an accident or an intentional act.

We regard both criticality accidents and releases from nuclear reactors as N incidents. All incidents involving nuclear weapons are out of scope for this project and will not be considered.

The production, acquisition and use of biological threat compounds and toxic chemicals in war, terrorist actions and sabotage have been banned by the Biological and Toxin Weapons Convention (BTWC, 1972) and the Chemical Weapons Convention (CWC, 1993). These international treaties also provide definitions which we use in this project.

Numerous chemicals may pose a threat to humans, animals or the environment due to their toxicity, flammability or reactivity, or a combination of these properties. In this project we focus on chemicals that may pose a threat due to their **toxic effects** primarily on humans, in accordance with the definition of a toxic chemical in the CWC. This means that incidents involving explosives, highly flammable and reactive substances are not included.

The following table gives key definitions used in this project.

Term	Definition
Biological (B) threat compound	Biological threat compounds comprise micro-organisms, *i.e.* bacteria, rickettsia and viruses, and toxins, which cause disease in humans, animals or plants.
Chemical, Biological, Radiological and Nuclear (CBRN) incidents	CBRN incidents encompass all events in which exposure to C, B, or R threat compounds cause great harm to the health of people, animals and/or the environment, as well as incidents in which N materials undergoing fission cause harm through dispersed radioactive fission products or by direct irradiation. Such incidents may be caused by an accident or an intentional act.
Chemical (C) threat compound	Chemical threat compounds are chemicals that may pose a threat to humans or animals due to their toxic effects. **Note**. Numerous chemicals may pose a threat to humans, animals or the environment due to their toxicity, flammability or reactivity, or a combination of these properties. For the purpose of this project, C threat compounds are delimitated to those chemicals which pose a threat primarily due to their toxic effects.
Nuclear (N) material	Materials able to undergo fission, thereby creating radioactive fission products and giving off direct radiation.
Radiological (R) threat compound	All radioactive substances can potentially be harmful if people are exposed. The determining factors are the rate and duration of the irradiation, and whether the exposure is internal or external.
Terrorism	The European Union's (EU) Council Framework Decision of 13 June 2002 on combating terrorism defines terrorism as intentional acts which "may seriously damage a country or an international organization" and are " committed with the aim of seriously intimidating a population, or unduly compelling a Government or international organization to perform or abstain from performing any act, or seriously destabilizing or destroying the fundamental political, constitutional, economic or social structures of a country or an international organization" (EU Council Framework Decision, 2002). The same

	definition was used by FOI in a 2006-report evaluating crisis management capacity in the EU (FOI, 2006)
Toxic chemical	Any chemical which through its chemical action on life processes can cause death, temporary incapacitation or permanent harm to humans or animals. This includes all such chemicals, regardless of their origin or of their method of production, and regardless of whether they are produced in facilities, in munitions or elsewhere. (CWC, 1993). The spectrum of toxic chemicals is wide and continues to expand. It spans from highly toxic chemical warfare agents, *i.e*. nerve- and blister agents, to toxic industrial chemicals, pharmaceuticals, bio-regulators and toxins.
Toxic Industrial Chemicals (TIC)	Toxic industrial chemicals (TIC) are industrial chemicals that are manufactured, stored, transported, and used throughout the world.
Toxin	Toxins are highly toxic chemicals produced by living organisms. The possible illegitimate use of toxins is covered by the prohibitions of both the CWC and the BTWC, thus toxins are, in principle, both biological and chemical threat compounds. However, it is most common to include toxins among the biological threat compounds due to their biological origin.

4. CBRN scenarios in previous projects

This chapter gives an overview of some CBRN scenarios used in previous projects, which are available for use in the PRACTICE project. These will be used as a basis for selection and development of the PRACTICE reference set of CBRN scenarios.

4.1 Scenarios in EU projects

4.1.1 IMPACT

The EU project "Innovative Measures for the Protection Against CBRN Terrorism (IMPACT)" developed the following scenarios in WP100, "A Representative Set of Planning Scenarios" by Cassel G., Norlander L., Olofsson G. and Svensson I. (Cassel, 2005):

1. B2 Biological agent delivered by mail
2. B3 Outdoor spread of biological agent
3. B4 Food factory contaminated with biological agent
4. B5 Infectious agent sprayed over international protest march

5. B7 SARS virus spread by air condition
6. C1 Nerve gas agent spread over a city centre
7. C2 Mustard attack on crowd
8. C3 Binary nerve agent released on a sports event
9. C4 Nerve gas in a metro car
10. H1 Unknown liquid sprayed over public at music festival
11. H2 Threat of mustard gas release
12. R1 Radiological attack in commercial centres
13. R2 Radioactive bomb at metro station
14. R3 Aeroplane crashes in a nuclear power plant reactor
15. TIC1 Poisonous chemical in drinking water system
16. TIC2 Explosion at industrial chemical site
17. TIC3 Toxic industrial chemical spread at a sports arena
18. TIC4 Toxic gas let into air condition of big office building

4.1.2 ASSRBCVUL

The EU project "Assessment of the vulnerabilities of modern societies to terrorist acts employing radiological, biological or chemical agents with the view to assist in developing preventive and suppressive crisis management strategies (ASSRBCVUL)" developed scenarios reported in the report for Deliverable #9. Final report (2007) (Leeuw, 2007).

1. B1 Intestine pathogens in hamburger dressing
2. B2 Plague in EU building
3. B3 Anthrax in a city centre
4. B4 Foot and mouth disease
5. C1 Contamination of food in flight catering system
6. C2 Arsenic compound in beverage
7. C3 Chloropicrin at subway station
8. C4 SO2 at sports arena
9. R1 Radioactive nuclide in juice
10. R2 Radioactive source in shopping mall
11. R3 Dirty bomb in a city centre
12. H1 Threat to release mustard gas

4.1.3 GSCT

In the EU project "Development of Generic Scenarios for Release of Chemicals by Terrorists (GSCT)" the following scenarios were developed by Cassel G., Andersson Å., Burman J., Berglind R., Eriksson H., Holst J., and Persson S. (Cassel, 2007):

1. Lorry tanker (Volatile Toxic industrial chemical (TICs) dispersed) in urban area

2. Lorry tanker (Volatile TICs dispersed) in an arena
3. Lorry tanker (Volatile TICs dispersed) in open space
4. Backpack (Chemical warfare agent (CWA)dispersed) in urban area
5. Backpack (CWA dispersed) in enclosed area
6. Backpack (Highly toxic substance dispersed) in enclosed area
7. Backpack (Physically incapacitating agent dispersed) in enclosed area
8. Solid TIC dispersed in water supply system
9. Solid TIC dispersed in foodstuff

4.1.4 MASH

The EU project "Mass casualties and health care following the release of toxic chemicals and radioactive material (MASH)" developed scenarios which are reported in "Mass-casualties and health care following the release of toxic chemicals or radioactive materials", WP 4 deliverable, "Scenarios" by Cassel G., Eriksson H. and Sandström B. (Cassel, 2008):

1. C1 Dispersion of persistent agent in urban area
2. C2 Release of toxic industrial chemical in semi-closed area
3. C3 Release of toxic industrial chemical in open space
4. C4 Dispersion of unknown liquid in enclosed area
5. R1 Radiological dispersal in urban area
6. R2 Improvised radiation device (IRD) in enclosed area

4.1.5 CIE Toolkit

The EU project "Chemical Incidents Emergencies (CIE) Toolkit" developed scenarios in WP6 "Exercise Card Concept. Exercise Director Instructions and Scenarios", reported by Cassel G., Sandström B., Norlander L., Thorstensson M., and Eriksson H. (Cassel, 2011):

1. Dispersion of toxic liquid in enclosed area
2. Dispersion of persistent agent in urban area
3. Toxic industrial chemical release in semi closed area
4. Toxic industrial chemical release in open space
5. Release of radioactive material in urban area
6. Dissemination of toxic chemical in foodstuff
7. Release of biological agent in enclosed area

4.2 Other scenarios

4.2.1 Intentional Release of Harmful Substances. Dispersion and Impacts on Society

Scenarios in "Intentional Release of Harmful Substances. Dispersion and Impacts on Society" (2002). (In Swedish: Avsiktliga utsläpp av skadliga ämnen. Spridning och samhällskonsekvenser) by Burman J., Björnermark M., Fell A., Lundgren N.G., Thaning L., Weissglas G. (Burman, 2002) are:

1. Dispersion of anthrax spores at a market place
2. Dispersion of sarin in a subway station
3. Dispersion of sulphur dioxide in a football stadium

4.2.2 The United States Planning Scenarios

The Homeland Security Council (2004) published the United States disaster planning scenarios for the Department of Homeland Security in July 2004:

1. Nuclear Detonation: 10-kiloton Nuclear Device
2. Biological Attack: Aerosolized anthrax
3. Biological Disease Outbreak: Flu Pandemic
4. Biological Attack: Pneumonic Plague
5. Chemical Attack: Blister Agent
6. Chemical Attack: Toxic Industrial Chemicals
7. Chemical Attack: Nerve Agent
8. Chemical Attack: Chlorine Tank Explosion
9. Natural Disaster: Major Earthquake
10. Natural Disaster: Major Hurricane
11. Radiological Attack: “Dirty Bombs”
12. Explosives Attack: Improvised Bombs
13. Biological Attack: Food Contamination
14. Biological Attack: Foot and Mouth Disease
15. Cyber Attack

4.2.3 Project Big City – Stockholm

In Project Big City – A Summary of Disaster Medical Resources in Stockholm County (Socialstyrelsen, 2006) several relevant scenarios are used (In Swedish: Projekt Storstad. En sammanställning av Stockholms läns katastrofmedicinska förmåga):

1. Trauma – The Madrid terrorist attack in Stockholm
2. Road transport accident causing leakage of ethylene oxide
3. Terrorist attack - Dispersion of sarin in an ice hockey stadium
4. Influenza pandemic (A/H5N1) originating from Asia
5. Deliberate potable water infection causing campylobacteriosis
6. Release of radioactive substances after air crash

4.2.4 Swedish Threat and Risk Scenarios

In “Scenarios for Threat and Risk Assessments. Collaboration Area for Hazardous Substances (in Swedish: Hot- och riskvärderade scenarier. Samverkansområdet Farliga ämnen)” (MSB (Swedish Civil Contingencies Agency, Myndigheten för samhällsskydd och beredskap), 2010, the following scenarios are given:

1. RN1 Local dispersion of radioactive substances
2. RN2 Deliberate contamination of radioactive substances in the food chain
3. RN3 Nuclear power plant accident
4. C1 Fire in a chemical warehouse
5. C2 Tank-car accident knocks out water supply
6. C3 Terrorist attack against dangerous goods transport
7. B1 Verotoxin-producing *Escherichia coli* outbreak in cattle and human infections with hemolytic-uremic syndrome
8. B2 *Salmonella* in feed
9. B3 West Nile virus infections in horses
10. B4 Outbreak of foot-and-mouth disease
11. B5 Alleged dispersion of anthrax spores in an opera house
12. B6 Influenza pandemic
13. B7 Outbreak of growth-inhibiting nematodes that spread with wooden packing
14. B8 Laboratory accident causing large exposure to *Legionella*
15. B9 Mycotoxins in grain

4.2.5 Indoor dispersion of sarin

FFI has published a scenario “Consequence assessment of indoor dispersion of sarin – A hypothetical scenario” by Endregard M., Petterson Reif B.A., Vik T., and Busmundrud O, (2010):

1. Consequence assessment of indoor dispersion of sarin – a hypothetical scenario

5. Historical cases of CBRN terrorism

This chapter describes a selection of the most well known acts of CBRN terrorism which caused human deaths or disease in the general population. There have been cases of chemical, biological and radiological attacks, assassinations and attempted assassinations, on individuals, but these incidents do not fall under our definition of terrorism. Hence, they are outside the scope of PRACTICE and will not be included here.

State use of CBRN weapons in warfare or against its own population is excluded from our examples for the following reasons: Warfare is not terrorism. State use of CBRN weapons against its civilian population can be defined as state terrorism. The PRACTICE project focuses on emergency preparedness and response to CBRN incidents within the EU member and associated countries. Acts of state terrorism using CBRN means will not be included in the reference set of CBRN scenarios, and are therefore also excluded from our examples in this chapter.

Radiological terrorism affecting more than one person has not been successfully carried out. However, there is apparently one incident from Moscow in 1995 that had potential to develop into something bigger. Chechen rebels informed a television company that they had placed a dirty bomb comprising Cs-137 in the Izmailovsky park in Moscow. There are several media mentions of the incident, and IAEA refers to this incident in a press release concerning control of radioactive sources, but the WP team has not been able to confirm any details concerning the episode (IAEA, 2002a).

There are no examples of nuclear terrorism. This chapter describes two biological and two chemical attacks which have been well documented.

5.1 Dispersion of *Salmonella* in Oregon in 1984

The dispersion of *Salmonella* in Oregon was the first incident of biological terrorism in the United States. It was between August and September 1984 that more than 751 people contracted salmonellosis in a small town in Oregon in the United States. A religious cult known as the Rajneeshees had contaminated salad bars in 10 restaurants with the biological agent *Salmonella enterica serovar Typhimurium*. According to the Rajneeshees, their motive was not to kill the citizens in Oregon, but to make the inhabitants sick so that they could not vote during the upcoming election (Tucker 2001:123). The Rajneeshees wanted to influence the election because they demanded autonomy from the authority of Wasco County.

The Health Department of Wasco-Sherman County received information about the first food poisoning on September 17, when a person fell ill after eating at a local restaurant. During the next four days, 25 people were infected by *Salmonella* at various restaurants in the district (Tucker 2001:130). The number of contaminated people continued to increase during the next weeks, and by 30 September, the number of *Salmonella*-infected persons had reached 423. The capacity at the Mid-Columbia Medical Center was not large enough to cope with all the patients, as it was the only hospital in the Wasco County. Even though no people died as a result of the *salmonella*-outbreak, more than 751 people fell ill during August and September 1984.

It is unknown why the Rajneeshees decided to use *Salmonella enterica serovar Typhimurium*. Ma Anand Puja, a nurse and the director of the Shree Rajneesh Ashram Health Center, was responsible for the acquisition of *Salmonella* and the laboratory activities leading to the incident. She was also a member of Rajneesh. Puja had been in contact with an urologist at the clinic, asking him about poisons that could make people sick. She also wanted an agent that was difficult to detect, and even though the urologist did not have any suggestions about poisons, he told her about *Salmonella* (Tucker 2001:124).

The Rajneesh Medical Cooperation (RMC) ordered a set of disks containing *Salmonella enterica serovar Typhimurium* from a company in Washington, known as VWR Scientific. This happened legally as the RMC had a legitimate need for it as “the agent was one of the control organisms used to meet the requirements for quality assurance expected of licensed clinical laboratories” (Tucker 2001:127). Parambodhi, a laboratory technician at RMC, had the competence to cultivate the *Salmonella*, and in cooperation with Puja and a third cult member, they were responsible for the laboratory activities. In all, approximately fourteen members were involved in the plot. Eight of these members were responsible for spreading the *Salmonella*, while only Puja and two other members were involved in the laboratory activities.

5.2 Sarin dispersal in Matsumoto and Tokyo in 1994 and 1995

The most infamous acts of chemical terrorism are the sarin attacks conducted by the doomsday cult Aum Shinrikyo in Japan in 1994 and 1995, respectively (Tucker, 2000; Tu, 2002; Tu, 2007). This cult was established by Shoko Asahara in 1987. In 1994 the cult had about 40 000 members; 10 000 in Japan and 30 000 in Russia, and some members in the US, Germany and Australia. The active core members consisted of about 1 400 persons who donated all property to the cult and lived on the cults premises. The cult had substantial economic resources and many followers with technical-scientific background, thus both resources and competence to produce chemical and biological threat compounds. From early 1990 the cult started experimental production of both C and B agents. In the period 1990 – 1993 the cult attempted to spread the biological agents botulinum toxin and anthrax bacteria in Tokyo, but did not succeed. The cult built a sophisticated facility for mass production of sarin in ton quantities and had purchased huge amounts of precursor chemicals. The facility never started full production due to police investigations.

On 27 June 1994 the cult performed their first act of chemical terrorism using the nerve agent sarin. The motive was to kill three judges involved in a court case against the cult. The sprayer was mounted in a wagon and placed in a parking lot in the residential area of the judges. Approximately 30 kg of sarin were dispersed in the residential area over a period of about 10 minutes. Seven persons were killed and hundreds poisoned.

The most well-known chemical terrorist attack occurred 20 March 1995. The cult's motive was to stop police investigations against the cult's activities by attacking the subway station closest to the Tokyo Metropolitan Police headquarters. The attack occurred during the morning rush hours. The sect members left eleven bags in five subway wagons in three different subway lines all heading for the same station. The plastic bags were punctured using umbrellas. The bags contained about 6 liters of impure sarin (30 %). The terrorist attack resulted in 12 deaths and thousands poisoned and seeking medical care.

5.3 Anthrax letters in the United States in 2001

After the terrorist attacks in the United States on 11 September 2001 an outbreak of anthrax occurred. Anthrax is caused by the spore-forming bacterium *Bacillus anthracis*. The disease occurs in three forms dependent on the route of exposure; inhalational, cutaneous or gastrointestinal anthrax, of which inhalational anthrax has the highest lethality. The first victim was diagnosed with inhalational anthrax on 4 October 2001 and died the subsequent day. More cases appeared, in total 22 persons, of which five died (Department of Justice, 2010). This spurred the creation of an investigative task force consisting of the Federal Bureau of Investigation (FBI), the United States Postal Inspection Service (USPIS) and other agencies. An intense, lengthy and complex investigation followed.

At first the cause of the outbreak was unknown, whether it was a state actor, an international terrorist organization, a US based group or an individual. New scientific methods for genetic testing were developed and proved crucial to identify the origin of the pathogen. By 2007, investigators concluded that the anthrax spores stemmed from a single spore-batch created and maintained at the United States Army medical Research Institute of Infectious Diseases (USAMRIID). The *Bacillus anthracis* strain is called Ames, and was isolated from a natural outbreak in Texas in 1981, shipped to USAMRIID and kept there. In 2008 the investigators concluded that the attacks were performed by Dr Bruce E. Ivans, a microbiologist working at USAMRIID and considered a leading anthrax specialist. The authorities prepared to charge him for the attacks, but in late July 2008 Ivans committed suicide. The Department of Justice announced the closure of the investigation on 19 February 2010 and published the Amerithrax investigative summary (Department of Justice, 2010). According to FBI, Ivans was under personal and professional pressure, and his motive was fear that his research programme for an anthrax vaccine should be shut down if no incident occurred.

The Task Force concluded that Ivans was the sole perpetrator and had mailed letters containing powder with anthrax spores to two Democratic Senators and media on two occasions. The investigators recovered the letters to the New York Post and NBC News which was postmarked 18 September 2001 and the letters to senators Dashle and Leahy postmarked 9 October 2001. In total at least 22 persons contracted the disease, of which 11 cases were cutaneous anthrax and 11 the inhalational form. Five persons with inhalational anthrax died in the period 4 October to 21 November 2001 in Florida, New York, Washington DC and Connecticut. Approximately ten thousand people underwent antibiotic treatment to prevent them from contracting the disease. The attack caused widespread contamination of mailrooms and public buildings. Some buildings were closed for years. The clean-up was extremely costly, exemplified by the $27 million spent to decontaminate facilities at Capitol Hill.

Even though the case has been closed by United States authorities, a debate continues about the evidences and conclusions drawn that Ivans was the perpetrator. A scientific committee has reviewed the scientific methods used, and their findings were published by the National Research Council in 2011 (National Research Council, 2011). According to CNN the report concludes that “it is not possible to reach a definitive conclusion” (CNN, 2011). Department of Justice issued a press release responding to the report with the main message being that their conclusions are not based on scientific evidence alone, but also on other investigative results and evidence (Department of Justice, 2011). The debate will probably continue.

6. Historical cases of CBRN accidents

The selected historical CBRN accidents in this chapter were chosen for three main reasons. First, the consequences of all selected accidents could have been more catastrophic, for example if these incidents had happened in a more populated area. Second, all accidents could have been intentional acts. Third, detailed descriptions of the selected accidents are accessible in various reliable sources. It should be noted that the selection of incidents in this chapter is not based on a comprehensive survey. The aim in this report is to give examples of relevant incidents for later CBRN scenario development. Important incidents may therefore be left out here.

6.1 Chemical accidents

This chapter gives an overview of some chemical accidents. An overview of all these incidents is given in Table A.1 (Appendix A).

6.1.1 Transport accidents

6.1.1.1 Ammonia train accident near Minot, USA, 2002

On 18 January 2002 at night time, a freight train derailed 31 of its 112 rail cars near Minot in North Dakota, the United States. Five tank cars, each containing up to 70 tonnes anhydrous ammonia, sustained serious damages and ruptured leading to an instantaneous release of the entire content, in total about 338 tonnes. In addition, other tank cars were punctured and started leaking resulting in the release of 170 tonnes over the next five days. The inversion weather conditions, *i.e*. low ground temperatures contributed to keeping the ammonia cloud close to the ground as it gradually travelled 8 km downwind over a populated area with about 11 600 people. One local resident died as a result of ammonia exposure, 11 persons were seriously injured, while 322 people sustained light injuries. The total damages exceeded $2 million, and the environmental remediation costs were $8 million. A thorough assessment has been undertaken by the National Transportation Safety Board (NTSB) (NTSB, 2004).

The probable cause of the accident was ascribed to an ineffective Canadian Pacific Railway programme and practice for inspection and maintenance of the rail. Cracked joint bars were not replaced, then completely fractured and led to the breaking of the rail. As a result of the accident the improved rail maintenance and inspection procedures have been improved.

The accident report concludes that the emergency response was effective. The Minot emergency services had conducted a disaster preparedness exercise in September 2001. This contributed to effective disaster management. The railroad accident report also concludes that the Fire Department decision to shelter all residents inside their homes during the release was an effective emergency response measure.

6.1.1.2 Chlorine rail car accident in Macdona, USA, 2004

On 28 June 2004, two trains collided near Macdona, Texas, in the United States. A tank car containing 90 tonnes of chlorine ruptured, resulting in a chlorine release of 60 tonnes. 78 000 gallons of urea fertilizer were also released, in addition to diesel fuel from the four derailed locomotives (Aristatek, 2007). The conductor of the Union Pacific train was killed, while two residents died from chlorine inhalation. In addition, 43 people were hospitalized due to chlorine inhalation. Responders from the Southwest Volunteer Fire Department were the first to arrive on the scene. They reported driving into a “yellow cloud” of an unknown substance (Aristatek, 2007).

Emergency personnel had problems rescuing nearby residents because of the train derailment which blocked the main road (Aristatek, 2007). A flooded river made the rescue even more complicated. In addition, the emergency personnel did not possess sufficient personal protective equipment, making the rescue less efficient. When a team finally entered the area and reached the residents, many of the residents were in considerable respiratory distress (Aristatek, 2007). The two people who died from chlorine inhalation were reached approximately seven hours after the accident.

In the aftermath of the accident, there has been some criticism regarding lack of coordination between the responding agencies (Aristatek, 2007). It has also been highlighted that the residents could have been rescued sooner. The cleanup costs of the chlorine spill near Macdona were estimated to approximately $7 million (Aristatek, 2007).

6.1.1.3 Chlorine accident in Graniteville, USA, 2005

On 6 January 2005, a Norfolk Southern train containing chlorine collided with a parked locomotive in Graniteville, South Carolina, in the United States, resulting in a major chlorine release. A crew had used the rail switch but forgotten to set the switch back to the main line, sending the train onto a wrong track and into a parked locomotive (Mitchell *et al*., 2005). One wagon containing 131 tonnes of chlorine ruptured and released 70 percent of its contents (Mitchell *et al*., 2005). The train also carried one railcar with liquid sodium hydroxide and one rail-car with liquid creosol. The train travelled at 45 miles per hour from Macon, in Georgia, to Columbia, in South Carolina, when fourteen railroad cars derailed in Graniteville (Mitchell *et al*., 2005). Nine people died after inhaling chlorine, and it is estimated that 550 people needed medical assistance. About 5 400 people had to evacuate as a result of the chlorine spill.

6.1.1.4 Train derailment in Kungsbacka, Sweden, 2005

On 28 February 2005, a freight train derailed in the vicinity of Kungsbacka, Sweden. The train contained 12 wagons, each of them carrying 65 tonnes of chlorine. The accident occurred due to a failure in the attempts to stop when turning out on a blind track to await a meeting train. This resulted in derailing of the engine together with four wagons running into the surrounding field. Fortunately, none of the tanks were damaged, there were no leakage, and the following rescue operations went fairly well (Ivansson, 2005). It should be noted that this accident is not a chemical incident since no release of toxic chemical occurred. It has, however, been included in this report since possible consequences of release of chlorine have been thoroughly evaluated.

After the incident, the Swedish preparedness in responding to chemical accidents was reviewed (Eriksson *et al*., 2007). Simulated consequences based on three models of hypothetical release scenarios and associated questions, indicated severe gaps in preparedness if chlorine had been released. Release of chlorine would have caused severe consequences for people in the dissemination area, as none of the emergency services involved were prepared to handle such a scenario. Also, due to the fact that accidents involving toxic industrial chemicals in Sweden are rare, the knowledge and practical skills were limited. The report pointed out that the health services had to prioritize medical countermeasures before decontamination, at least after release of chlorine and other condensed gases or pressurized liquid chemicals. To achieve an effective minimization of the outcome of chemical accidents, comprehensive planning, education and training for all organizations involved should be required.

6.1.2 Chemical plant accidents

6.1.2.1 Chemical plant accident in Seveso, Italy, 1976

On 10 July 1976, Italy experienced an accident at a chemical manufacturing plant near the town of Seveso, situated in the north of Italy. A reactor was overheated, and when a burst disc ruptured, part of the contents of the vessel was released through an exhaust pipe on the roof, filling the air with a toxic cloud containing 2,3,7,8 tetrachlorodibenzoparadioxin (TCDD), a highly toxic form of dioxin (Wilson, 1982). The cloud of dioxin contaminated a land area of about 17 km^2, making about 4 km^2 of the area uninhabitable (Kletz, 2001). The reactor manufactured pesticides and herbicides. There were no fatalities, but more than 600 people were evacuated from their homes and 2 000 people were treated for dioxin poisoning (European Commission, 2010). The TCDD also had carcinogenic effects on the population living near Seveso at the time of the accident (Wilson, 1982). In addition, there was a significant ground contamination with delayed injury on herbivores and on the human population (Bourdeau *et al*., 1989).

The accident was unexpected. Accident scenarios for the Seveso facility had been developed, but none of these scenarios were similar to the actual reactor release (Caragliano, 2007). The authorities did not receive information about the TCDD emission right away, which further delayed the implementation of safety management systems (Bourdeau *et al*., 1989). Only when four children at an elementary school fell ill, were the emergency services alerted (Caragliano, 2007). The Local Operating Manual, which gives information on how to manage chemical emergencies, had not been distributed to all relevant actors ahead of the accident (Caragliano, 2007).

The accident in Seveso prompted the Council of the European Union to adopt the Council Directive 82/501/EEC on the major-accident hazards of certain industrial activities, the so-called Seveso Directive, in 1982, which is a safety regulation relevant to all operators of industrial establishments who handle hazardous materials in large quantities.

6.1.2.2 Gas leak disaster in Bhopal, India, 1984

One of the worst industrial accidents in history is the Bhopal gas leak disaster in India on 2-3 December 1984. About 42 tonnes of highly toxic methyl isocyanate (MIC) gas was released from a storage tank at the Union Carbide India Limited (UCIL) pesticide plant. It was water in the storage tanks that caused an exothermal reaction releasing poisonous gas, which then caused the opening of the safety valves (Enzler, 2006).

It is estimated that about 2 500 people in the surrounding community died as a result of the accident, while more than 200 000 people were exposed to the toxic gas (National Board of Health and Welfare, 2000). After evaluating the safety system at the UCIL in 1982, the Union Carbide Corporation Staff had in fact concluded that there were numerous safety deficiencies at the facility (Tweeddale, 2003). There had for instance been smaller leaks from the plant. The majority owner and operator of the pesticide factory, the American company Union Carbide, had to pay $470 million in compensation to the affected victims (Broughton, 2005). Many European countries responded to the Bhopal release by implementing stricter regulations on the storage and production of hazardous materials. In India, however, plant chemicals were still at the site in 2004, despite the chemicals being banned there by the authorities in 1985 (Willey *et al*. 2006).

6.1.2.3 Cyanide spill in Baia Mare, Romania, 2000

In the process of purifying gold from rock, cyanide salt is used. On 30 January 2000, a tailings dam at the Arul Mine in Romania overflowed, and released 100 000 cubic meters of fluid containing cyanide into the Tisza River. It was a breach in the dam that surrounded a settling basin that caused the major cyanide spill. The waste water contained cyanide, but also copper, zink and lead. Rumanian authorities immediately raised the alarm, which prevented any human victims (Enzler, 2006). However, according to some sources (BBC, 2000), up to 100 people, mostly children, have been treated in hospital after eating polluted fish. Heavily contaminated wastewater reached the river Danube (Donau) and moved on to Hungary, Serbia and beyond. Traces of cyanide were still detected in the river water when it reached the Black Sea two weeks later.

Some things worked really well during the Baia Mare spill. For instance, the early warning system alerted downstream authorities of the polluted water coming their way (Balkau, 2010). Villages downstream were also able to make other arrangements for drinking water. Attempts to neutralize the cyanide in the river however, were rather unsuccessful. It only added more noxious chemicals to the water (Balkau, 2010).

6.1.2.4 Ammonium nitrate explosion in Toulouse, France, 2001

This accident is an explosion, thus outside the scope of PRACTICE. However, at nearby facilities both chlorine and ammonia were stored. Hence, the accident had potential also for release of toxic gasses as a secondary effect of the explosion, and therefore deemed relevant in our context.

On 21 September 2001, France experienced one of the country's largest industrial accidents. A massive explosion of ammonium nitrate occurred in the AZF facility, a plant producing fertilizers and a variety of chemical products only 3 km from the city of Toulouse. About 300-400 tonnes of ammonium nitrate was stored in the facility when the explosion occurred, and it is estimated that 40-80 tonnes of the material was detonated (General Inspectorate for the Environment, 2001). The explosion occurred at 10:17 am. Windows in buildings several kilometres from the site were blown out, and the explosion produced a crater of about 40 meters in diameter and 7 meters in depth (General Inspectorate for the Environment, 2001). The explosion caused the death of 30 people, whereas 22 of these people were killed at the site. Approximately 2 500 people were injured.

Nearby facilities stored considerable amounts of ammonia and chlorine. Some of these buildings were damaged in the explosion, but the tanks inside did not suffer any damage. All plants were required to stop its activities immediately after the explosion, and taking into consideration that the AZF facility was situated so close to the centre of Toulouse (General Inspectorate for the Environment, 2001), the consequences of the crisis could have been more dramatic if these facilities were also damaged in the explosion. The crisis raised a public debate in France about industrial risks and urbanization near hazardous plants (Dorison, 2001), leading in 2003 to an improvement of regulations and safety conditions concerning industrial risks, public information and crisis management (Dorison, 2001).

6.1.2.5 Chlorine release accident in Festus, USA, 2002

On 14 August 2002, around 9:20 a.m., liquefied chlorine was transferred from a tank car to the DPC Enterprises plant near the city of Festus, Missouri, in the United States. According to the U.S. Chemical Safety and Hazard Investigation Board (CSB), one of the hoses used to transfer the chlorine burst during the operation, and 22 tonnes of chlorine gas was released over a 3 hour period (CSB, 2002). The chlorine release activated a chlorine detection alarm. When hearing the alarm, the employees evacuated the building, and the operation manager pushed the emergency shut-off button (CSB, 2002). However, both automatic and manual shutdown systems, which were designed to shut off accidental releases of liquid chlorine, failed to work. The chlorine release continued for about three hours before responders from the Jefferson County Hazardous Materials Team (HAZMAT) managed to close the car valves and stop the leak. No people died as a result of the chlorine release, but 66 people sought medical attention and were monitored for respiratory distress. Three workers suffered skin exposure during cleanup activities.

According to the CSB, the DPC Enterprises was not prepared for a major chlorine release accident. The Board lists six main explanatory factors (CSB, 2002). Firstly, the guidelines for community notification were inadequate. Secondly, there was no clear designation of responsibility among the emergency team members. Thirdly, the guidelines did not determine when a chlorine leak required assistance from off-site community HAZMAT teams or only response from the facility personnel. Fourthly, the DPC did not have timetables for training the facility personnel on emergency response. Fifthly, the emergency equipment was not easily accessible. Lastly, there were no guidelines for planning post-incident cleanup of hazardous materials. If such guidelines had existed, the three workers may not have been exposed to chlorine during clean-up. The CSB (2002) also pointed out deficiencies in the response plan of the Jefferson County, as the Jefferson County emergency plan had not been updated since 1996.

6.1.2.6 Ammonia tank accident in Vestfold, Norway, 2002

A release of ammonia from an overfilled tank at Kjøndal farm in Vestfold resulted in an explosion on 30 July 2002. The tank was placed on a tractor trailer and, due to temperature rise, the pressure inside the tank increased, leading to an explosion which made the lid blow off. The accident caused a debate regarding safety regulations on the widespread use of ammonia in agriculture and industry. Safety regulations stipulate that maximum filling of ammonia tanks must not exceed 86 %, as the last 14 % should be serving as a security volume for gas in case of varying temperatures. The ammonia filling level in the tank that exploded at Kjøndal farm had nearly reached 100 %.

One man died of gas poisoning as a result of the accident, while nine people were injured. In addition, five people were kept under medical observation after staying on a neighbouring farm situated in the direction the gas drifted. 187 cows also died immediately of gas poisoning, while 45 remaining cows had to be slaughtered (Brannmannen, 2002). Yara, previously a part of Hydro and responsible for overfilling the tank at Kjøndal farm, had to pay 1 million Norwegian kroner (approx. 125 000 EUR) in compensation to the affected victims at the farm.

According to the accident police report, the emergency personnel had not sufficiently taken into consideration the effects of wind direction (DSB, 2002), with reference to the five people staying at the neighbouring farm. The police report also emphasized the importance of having better clarification of roles and responsibilities in emergency management, and of increased cooperation and exercises between the emergency services in order to become more coordinated in emergency management (DSB, 2002).

6.1.2.7 Toxic sludge spill in Ajka, Hungary, 2010

On 4 October 2010, a tide of toxic waste hit the river Danube after a reservoir wall gave way at the MAL Zrt aluminum plant at Ajka, Hungary. Nine people were killed and approximately 150 people injured when a highly caustic red liquid from bauxite refining gushed over nearby villages, bridges, sweeping away people, cars, livestock and possessions (The Economist, 2010). In particular, a lot of people suffered serious burns and eye ailments as a result of the caustic mud.

Hungary responded quickly by declaring a state of emergency in the three nearby counties. The authorities also added substances to the Danube river to neutralize the material, and constructed underwater weirs to slow the mud and maintain it as much as possible (Dunai, 2010). These actions were important, especially because the Danube river flows downstream through Croatia, Serbia, Bulgaria, Romania, Moldova and Ukraine (Dunai, 2010).

Immediately after the accident, the Hungarian government took the Mal Zrt plant under temporary state control and froze its assets. The MAL Zrt denied any negligence, and claimed that the reservoir met the required standards.

6.2 Biological accidents and natural outbreaks

This chapter gives an overview of some biological incidents. An overview is given in Table B.1 (Appendix B).

6.2.1 The Sverdlovsk accident in 1979

In April and May of 1979, there was an outbreak of anthrax in the city of Sverdlovsk (now Yekaterinburg) in the former Soviet Union, a city of 1.2 mill inhabitants 140 km west of Moscow (Meselson *et al*., 1994). In 1980, Soviet officials and scientists reported that the outbreak was gastrointestinal and cutaneous anthrax cases caused by contact with and consumption of contaminated meat. The epidemic initiated an intense debate and suspicions by US officials that the outbreak stemmed from release of spores from a military microbiology facility, and that the activities here may be in violation with the Biological and Toxin Weapons Convention.

After the fall of the Soviet Union, in 1991, Yeltsin initiated an investigation, and in May 1992, Yeltsin was quoted: “the KGB admitted that our military developments were the cause”. In 1992 and in 1993, a group of US scientists visited Sverdlovsk (Meselson *et al*, 1994). The group published an article together with Russian scientists which reports epidemiological investigations of 66 deaths and 11 survivors. The study concludes that the pathogen was airborne with a release location consistent with the military microbiology facility. According to Alibek the cause of the accident was a missing filter in an exhaust pipe where the anthrax cultures were dried to produce anthrax powder which can be dispersed as aerosols (Alibek *et al*., 2000). It had been removed due to clogging and not replaced. It is the largest documented outbreak of human inhalational anthrax. An estimate suggests that about one mg of spores were released (Meselson *et al*., 1994).

6.2.2 Food-borne botulism in the United Kingdom during the period 1989 to 2005

Food-borne botulism is a rare but serious disease caused by ingestions of neurotoxin [botulinum neurotoxins (BoNTs)] produced as a result of the growth of the bacterium *Clostridium botulinum* in foods before consumption. (McLauchlin *et al*., 2006). The disease is rare in the United Kingdom, and only 62 cases have been recognized between 1922 and 2005. There were six episodes (33 cases with three deaths) of this disease that occurred in the United Kingdom between 1989 and 2005. The six incidents illustrate the importance of the risk factors of poor processing or storage of commercially prepared foods, improper home preservation of foods and travel to countries where botulism is much more common than in the United Kingdom. Even small outbreaks of food-borne botulism can precipitate a national emergency and inundate public health and acute care provision. Since 1989, there has been six incidents (33 cases with three deaths) detected which are described as follows:

The first incident concerned the largest outbreak of food-borne botulism in the United Kingdom, and occurred in 1989 with 27 cases and one fatality associated with the consumption of commercially prepared hazelnut yoghurt. Subsequent laboratory tests showed that *C. botulinum* type B and BoNTB were detected in the faeces of one of the patients, opened and unopened cartons of yoghurt and the canned hazelnut conserve.

The second incident of food-borne botulism occurred in 1998. A husband and wife of Italian origins brought back to England from Italy and consumed home-preserved mushrooms in oil. Both family members developed botulism (one died), and *C. botulinum* type B and BoNTB were detected in serum and faeces of one patient as well as in the bottled mushrooms. The bacterium alone was recovered from the faeces of the patient who died.

The third incident in 2003, a male Polish national living in the United Kingdom developed botulism and subsequently died. BoNTB was detected in serum samples collected before death. The patient shared a meal with a second Polish national, which included a home-prepared meat product ('bigosh') brought from Poland. The second Polish national returned to his home country and was diagnosed with botulism.

The fourth and fifth incidents concerned two single food-borne botulism incidents in 2004. The first case was based on clinical diagnosis alone in a male adult patient who consumed commercially prepared hummus which had been inappropriately stored in the patient's home at room temperature for several weeks. The food was described as 'off' which is why no other family members consumed this product. Because of delays in investigating this patient, appropriate samples were not collected from the patient sufficiently early to confirm the clinical diagnosis. The patient recovered and was discharged without any specific anti-botulinum therapy. The second case was a female patient who returned to England from Georgia. *Clostridium botulinum* type A was recovered from the patient's faeces ~10–14 days after the onset of illness which commenced as the patient was returning to the United Kingdom. A food history was taken, and multiple traditionally prepared foods had been consumed just before leaving Georgia. This patient was also discharged without any specific anti-botulinum therapy.

The sixth and final incident occurred in a male Polish national living in England in 2005, who developed botulism within 24 h of consuming home-preserved pork originally prepared in Poland. *Clostridium botulinum* type B and BoNTB were recovered from the patient's faeces and from the jar of home preserved pork. The patient was treated with antitoxin and made a complete recovery. The preserved pork had been home slaughtered, bottled and stored at room temperature for several months in Poland before bringing to England for consumption.

6.2.3 Severe acute respiratory syndrome outbreak in 2003

Severe acute respiratory syndrome (SARS) is a viral respiratory disease caused by a coronavirus (CDC, 2011). SARS was first reported in Asia in February 2003. Over the next few months, the illness spread to more than two dozen countries in North America, South America, Europe, and Asia before the SARS global outbreak of 2003 was contained. According to the World Health Organization (WHO), a total of 8 098 people worldwide became sick with SARS during the 2003 outbreak. Of these, 774 died (WHO, 2011a). There were further cases in Singapore, Taiwan and China in late 2003 and 2004, but no cases after that are reported on the WHO situation updates (WHO, 2011b).

The main way that SARS seems to spread is by close person-to-person contact. Infection is usually acquired by droplet transmission during close contact with a symptomatic case, or by contamination of eyes, mouth or nose with respiratory secretions, body fluids, or faeces of a case. No antiviral drug or other drugs, such as steroids, have been proven to be effective and treatment is essentially of a supportive nature. In general, SARS begins with a high fever. The incubation period from exposure to onset of fever is 3-7 days. Most patients develop pneumonia. Other symptoms may include headache, an overall feeling of discomfort, and body aches. Some people also have mild respiratory symptoms at the outset. About 10 % to 20 % of patients have diarrhea. Those caring for cases are at high risk of becoming infected if infection control is inadequate. Rapid detection and early isolation of cases, and early and effective infection control, are central to control of SARS.

6.2.4 The H1N1influenza pandemic in 2009

The H1N1 2009 virus, a virus new to humans, was first detected in a 10 year old patient in California in April 2009 (CDC, 2010). Subsequently, additional cases in California and Texas were confirmed. Analysis of samples from Mexico showed that cases had appeared there prior to the cases in the United States. The new influenza virus then spread rapidly around the world. WHO monitored the situation closely in the period April to June 2009, and gradually raised the pandemic alert level. On 11 June 2009, WHO declared that a global pandemic of 2009 H1N1 influenza was underway by further raising the worldwide pandemic alert level to Phase 6. At that time, there were confirmed infections in 74 countries. To date, most countries in the world have confirmed infections from the new virus.

Since the H1N1 virus had not been seen in humans before, many people had no pre-existing immunity. The pandemic caused unusual and extensive outbreaks of disease in the summer months in many countries and very high levels of disease in winter months. The pandemic virus dominated over other seasonal influenza viruses. It also showed unusual clinical patterns where the most severe cases occurred most often in younger age groups. (CDC, 2010)

The pandemic H1N1 virus is spread from person to person by exposure to infected droplets expelled by coughing or sneezing that can be inhaled, or that can contaminate hands or surfaces. To prevent spreading, people who are ill should cover their mouth and nose when coughing or sneezing, staying home when they are unwell, clean their hands regularly, and keep some distance from healthy people, as much as possible.

On 10 August 2010, the WHO declared an end to the 2009 H1N1 pandemic globally. The 2009 H1N1 viruses and seasonal influenza viruses are co-circulating in many parts of the world. It is likely that the 2009 H1N1 virus will continue to spread for years to come, like a regular seasonal influenza virus (CDC, 2010).

When it comes to the consequences of the 2009 H1N1 pandemics we cite the WHO webpage (WHO, 2010):

> *“The global impact of the current pandemic has not yet been estimated. Typically, the numbers of deaths from seasonal influenza or past pandemics are estimated using statistical models. By contrast, the currently reported counts of over 16,000 deaths from pandemic H1N1 represent individually tested and confirmed deaths, primarily reported from countries with adequate resources for widespread laboratory testing. This approach has never been used to count seasonal or previous pandemic deaths and results in a significant underestimate. A more accurate assessment of mortality from the pandemic, using statistical models, will likely be possible in about one to two years.”*

6.3 Radiological accidents

This chapter gives an overview of some radiological accidents. An overview of all these incidents is given in Table C.1 (Appendix C).

6.3.1 Radiography equipment accidents

6.3.1.1 Radiography equipment accident in Gilan, Iran, 1996

On 24 July 1996, a construction worker on a building site was exposed to radiation when he picked up an unshielded 185 TBq Ir-192 source that had fallen out of an industrial radiography unit. After keeping the source in his shirt pocket for about 1.5 hours, the worker started to feel a burning sensation in his chest, and also noticed dizziness and nausea. He then put the source back at the spot where he had found it, where it was later found by the handlers of the radiography unit who had noticed that the source was missing. When the worker was still feeling unwell a few hours later, he informed his manager. The worker was sent for a medical examination. The other workers at the site were also tested, but no one else was found to show symptoms of radiation exposure.

Two days later, when the skin lesions were getting worse and his level of white blood cells were falling, he was admitted to hospital. On 16 August 1996 he was transferred to the specialist hospital Institute Curie in France where he was treated with skin grafts on his chest and right thigh. When examined 4.5 years after the accident, the worker was found to be in satisfactory condition, but still had some problems with his right elbow and left hand. The International Atomic Energy Agency (IAEA) published a report on the incident (IAEA, 2002b).

6.3.1.2 Radiography equipment accident in Yanango, Peru, 1999

On 20 February 1999, a radiological accident occurred at a hydroelectric power plant in Yanango in Peru. A welder found an Ir-192 source that had fallen out of an industrial radiography unit which had been used at the site where he was working. The worker picked up the source and put it in the pocket of his jeans and kept it there for the remainder of the work day. After a while he started to feel some pain in the back of his right thigh and after work he went to see a local doctor who after looking at the patch, which was now red and swollen, concluded that it was probably an insect bite.

The radiography team noticed the same night that the equipment was not working, and at around midnight they concluded that the source was missing. After searching the site with radiation survey meters, they went out to visit all the people who had worked on the site that day.

At one o'clock that night, the radiography operator and another engineer came to the home of the welder. Using a survey meter they could notice elevated levels of radiation outside the house. When the welder brought the source to the door, the operator told him to throw it out in the street. He then put a rock over it. The engineer stayed with the source while the operator went back to the site to find equipment to pick it up and secure it. The next morning, the worker was admitted to hospital. In May, he was transferred to a hospital in France. Despite intensive care, amputation of the right leg was unavoidable. IAEA published a report in 2000 on this incident (IAEA, 2000a).

6.3.1.3 Radiography equipment accident in Cochabamba, Bolivia, 2002

In April 2002, in Bolivia, an industrial radiography unit containing a 1.67 TBq Ir-192 source was transported as cargo on a passenger bus from Cochabamba to the capital La Paz, a distance of about 400 km. When the radiography unit reached the recipients in La Paz, it was discovered that the source had not been adequately retracted into the shielding after use. This meant that the driver and the passengers on the bus had been exposed to radiation during the eight hour journey.

Calculations after the incident showed that passengers on the bus in the worst possible case might have received up to 190 mGy. In addition to this, four workers involved in the handling of the equipment received doses up to 200 mGy. Finding the exposed bus passengers proved difficult, but the ones who were identified were tested and no serious health effects were observed. More information on this incident is documented in an IAEA-report (IAEA, 2004).

6.3.1.4 Radiography equipment accident in Nueva Aldea, Chile, 2005

On 14 December 2005, an Ir-192 source of about 3.33 TBq fell out of an industrial radiography unit on a factory building site. The handlers of the radiography unit did at first not notice this, and the source was found by a scaffolding worker, who handled it himself and showed it to two other workers who also handled it, trying to find out what it was. The worker then decided to take the object to his manager's office, where it set off an alarm on an electronic dosimeter in a neighbouring office. The worker then was instructed to put the source into an improvised metal container, from where it was later recovered and put back in the shielding material of the radiography unit.

The three workers and one radiography assistant needed medical treatment for skin lesions. The worker who found the source was most severely affected and was transferred to a hospital in France for further treatment. A total of 190 people who had been or might have been close to the source during the time it was unshielded were examined for possible radiation effects. The incident is described in (IAEA, 2009).

6.3.2 Orphan source accidents

6.3.2.1 The orphan source accident in Goiânia, Brazil, 1987

One of the most extensive accidents concerning a lost radiation source took place in Goiânia in Brazil in 1987. In 1985, a 50.9 TBq Cs-137 teletherapy source was left behind when a radiotherapy institute moved to new premises. In September 1987, two scavengers went into the unoccupied old clinic and found and removed the still encapsulated source. They later disassembled the source, compromising the encapsulation of the powdered radioactive material, and sold some of the pieces on to a scrap dealer. Over the next days the scrap dealers and several of their family members developed symptoms of radiation poisoning, but did not connect this to the source. Only about two weeks after the source had first been compromised, one of the affected people suspected that the material from the hospital equipment was connected to the illness, and brought the source to a local doctor. The doctor suspected the material might be radioactive and managed to get in contact with radiological expertise.

By the time the radioactivity had been identified and the government informed, radioactive powder from the source had already been spread over a large area including 85 buildings and 50 vehicles. Four people died as a result of radiation poisoning and 28 more received local radiation damage. 112 000 people sought medical attention, 600 were measured for contamination and 248 were actually contaminated. Details of the incident are documented in an IAEA report (IAEA, 1988).

6.3.2.2 The orphan source incident in Tammiku, Estonia, 1994

In October 1994, three brothers broke into a radioactive waste depository and stole a metal container. During the break-in, a Cs-137 source fell out of the container and one of the men picked it up and put it in his pocket. The source was later estimated to have been around 7 TBq. The same evening the man started to feel ill and was later admitted to hospital, vomiting and with severe burns on one leg. He died ten days later, on 2 November, 1994.

The death of the first man was not attributed to radiation, and the unshielded Cs-137 source was left at the man’s home with his family. The man’s stepson was admitted to hospital with burns on his hands on 17 November 1994. At this time, the family’s dog had also died. The injuries were now recognised by the doctors as radiation burns. The two other brothers and the other family members living in the house, a total of five people, were also admitted to hospital and treated for various radiation related injuries. The incident is reported in an IAEA report (IAEA, 1998).

6.3.2.3 The lost sources in Tblisi, Georgia, 1997

Lilo Training Centre in Georgia is a 150 000 m2 large military area outside of Tbilisi in Georgia, used for training and housing of soldiers and their families. Between April and September 1997, several soldiers developed skin burns, caused by radiation exposure. In late August, army radiation experts identified a hot spot of about 45 mGy/h on the premises. A working group of national experts was established to find the source of the radiation and contain the problem. After finding several unshielded sources at different locations in the area, the working group decided to do a full survey of the whole training centre. All in all, ten unshielded Cs-137 sources (0.2-164 GBq) and one small Co-60 source were found. In addition to this, two more Cs-137 sources still in their lead containers were also identified. Nine soldiers developed radiation burns as a result of this incident, but exact dose rates have not been calculated. The accident is detailed in an IAEA Report (IAEA, 1999a).

6.3.2.4 The orphan source accident in Istanbul, Turkey, 1998

A company specialising in transportation of radioactive material received three Co-60 sources from old cancer treatment equipment in 1993. The company applied for and received permission to export these sources to the United States, where the original supplier would dispose of them as radioactive waste. For unknown reasons, the sources were packed for shipping, but never actually sent. In 1998, two of the containers were removed from a storage facility in Ankara to a warehouse in Istanbul. When this warehouse was sold, the new owners found the containers and, not recognizing the symbol for radiation, sold them as scrap metal.

On 10 December 1998, the shielding was stripped off the sources, leading to radiation exposure of the workers in the scrap metal facility. Three days later, ten people who had worked in the proximity started showing symptoms of radiation poisoning, six of them vomiting. The cause of the illness was not identified until four weeks later when a doctor suspecting radiation poisoning contacted the authorities. In the meantime, at least one source had been left unshielded in a residential area for several weeks. The clean-up of the facility proved difficult. Only one source, an encapsulated Co-60 source of about 3.3 TBq, was found, and it is unclear whether the second container had contained a source at all. A total of 404 people were given medical examinations after the incident. 18 people, including seven children, were admitted to hospital, the five most severely affected stayed for 45 days. The accident is reported in an IAEA report (IAEA, 2000b).

6.3.2.5 Orphan source accident in Algeciras, Spain, 1998

In the end of May and early June 1998, four different sampling stations in a network of air monitoring stations in Slovenia detected an increase in Cs-137. The highest single measurement was 1.03 mBq/m3 in Ljubliana on 1 June 1998. No increase was found in rainwater samples. Measurement stations in other European countries found similar small increases. The release of Cs-137 was calculated to have been between 8 and 80 Ci, and originated from a steel factory plant in Algeciras in Spain, where a Cs-137 source probably had been melted down inadvertently as scrap metal. This incident is described in a report from Institute of Occupational Safety, Slovenia (1998).

6.3.2.6 The orphan source incident in Samut Prakarn, Thailand, 2000

In October 1999, an old teletherapy unit containing a Co-60 source estimated to be 15.7 TBq was stolen from an unprotected area where the company responsible for it stored it together with three other radioactive sources. A scrap dealer bought the equipment and took it home. On 1 February 2000, the scrap dealer and three other workers started to dismantle the equipment. When this proved difficult, they brought the unit to another scrap yard, where more people got involved. Several of the workers later felt ill and developed burn-like lesions on their hands, nausea and diarrhea.

Between 15 February and 18 February, several of the workers were admitted to hospital. The medical personnel who examined them suspected radiation poisoning and notified the authorities. A dispatched search team measured 1 mSv/h at the gate of the scrap yard. The area around the yard was fenced off, and an emergency response team sent in to find and secure the source. This was a difficult job, considering the high radiation levels in the area. Three people died as a consequence of this accident and seven others were exposed to high radiation doses, all workers at the scrap yard. The incident is described in an IAEA report (IAEA, 2002c).

6.3.2.7 The orphan source incident in Mayapuri, India, 2010

In February 2010, an old laboratory device made for gamma irradiation of materials, containing a Co-60 source, was inadvertently sold from the Chemistry Department at Delhi University to a scrap dealer. The scrap dealer subsequently dismantled the equipment and found the cobalt, in the form of 16 pencils, each containing seven metal pieces. After trying to cut up the material, several of the workers developed burns and other symptoms of radiation exposure. Doctors at a hospital recognised the symptoms and informed the authorities quickly. Eight people were exposed to high levels of radiation as a result of this incident, three were hospitalised and one died. This incident has been reported in the media. Information can be found in the Indian newspaper The Hindu (The Hindu 2010 a-d).

6.3.3 Irradiation equipment accidents

6.3.3.1 The irradiation equipment accident in San Salvador, El Salvador, 1989

In February 1989, an accident in an industrial radiation facility using a 0.66 PBq Co-60 caused severe radiation exposure to three workers. One subsequently died. The equipment used in the facility was old and had been manipulated and gone through provisional repairs several times since it was installed in 1974. Because of the ongoing civil war in El Salvador, the American supplier of the equipment had not been able to perform routine maintenance or operator training for years.

On the night of the accident, the radiation sources were stuck in an unshielded position during operation and an alarm went off. The worker making the night shift at the facility tried to get the sources down again, but only managed to manipulate the system in such a way that the alarm was shut off, but the sources were still exposed. This also overruled the automatic lock on the door to the irradiation room. The worker then cut out the power to the machine, believing that this would stop the radiation, and entered the room. After unsuccessfully trying to fix the problem with the machinery, the worker called in two other workers to help him. Shortly after leaving the room, the first worker began to feel ill. When he started vomiting blood, the other workers decided to take him to an emergency unit at a nearby hospital. Later, the two others also started showing symptoms and were admitted to the same hospital.

Three to four weeks after the accident, the three men were transferred to Mexico for further treatment. The first worker died from complications six months after the accident. The two others recovered, but one had injuries so severe that both legs were amputated.

The accident was at first not properly reported at the facility, and in the following days, three more workers received high doses of radiation after similar problems with the equipment, although not high enough to give immediate medical effects. The accident is detailed in an IAEA report (IAEA, 1990).

6.3.3.2 The irradiation accident in Soreq, Israel, 1993

On 21 June 1993, an operator at a commercial facility for irradiation of materials in Soreq in Israel accidentally entered the irradiation room while a 12.6 PBq Co-60 source was still in an unshielded position. The accident happened when a carton of the materials sent in for irradiation burst and the contents spilled out and hit the rack of cobalt sources in the irradiation machinery. This distorted the rack enough to keep it from being lowered into the shielded position. At this point, a fault in the safety systems caused two conflicting signals. A sound alarm was indicating a very high level of gamma radiation in the room. However, a lamp on the operating panel falsely indicated that the source rack was in the safe shielded position. An operator, being in a hurry and remembering a previous fault with the gamma alarm, assumed that the room was safe and entered it to fix the problem with the burst carton manually. After being in the room for about a minute, the operator felt the radiation effect and left quickly. The operator then informed his manager of the accident, and was sent to hospital, where he, despite intensive care, died 36 days later. The accident is described in an IAEA report (IAEA, 1993).

6.4 Nuclear accidents

This chapter gives an overview of some nuclear accidents. An overview is given in Table D.1 (Appendix D).

6.4.1 Nuclear reactor accidents

6.4.1.1 The nuclear reactor accident on Three Mile Island, USA, 1979

The nuclear accident known as the Three Mile Island accident started at around 4 a.m. 28 March 1997, in the second unit in the Three Mile Island power plant, situated on an island in the Susquehanna River about 16 km from the capital of the State of Pennsylvania, Harrisburg. The reactor was a 3000 MWt (1000 MWe) pressurized water reactor (PWR). The fuel elements were encapsulated with a special alloy containing zirconium, a material that is commonly used in nuclear facilities. The reactor was fairly new and had only been operating for about three months.

It is not altogether clear how the accident started, but the problem originated in the secondary cooling system, which shut down at 4 a.m. One source (Collins *et al*., 1982) claims that this was caused by a procedure trying to correct a problem in the cleaning system for the water in the secondary circuit. In an effort to clean out the ion-exchange columns, the operators tried blowing a mixture of water and air into it, but this caused the automatic valves letting the cooling water through to close. According to Collins, there was a by-pass lane around the cleaning system, but this was closed off by a manual valve on the night of the accident. The control rods were inserted and the reactor was shut down, but the fuel elements in a nuclear reactor will still produce heat and require cooling after the fission process has been stopped.

Without the secondary cooling, the water in the primary cooling system of the reactor became overheated, and a relief valve was opened to release the increased pressure. The relief valve should have closed again as the pressure normalised, but did not. This was not understood by the operators of the reactor. An automatic emergency cooling water system started sending more water into the primary circuit at this point, but the operators, misinterpreting the signals from the system, believed there was still too much pressure in the primary cooling circuit, and turned it off again.

The increased temperature and open pressure relief valve caused the water level in the primary cooling circuit to drop, leaving the top of the fuel rods exposed, which led to further overheating. The rod cladding ruptured and the fuel elements started to melt, allowing radioactive gases and water soluble materials to be released out into the cooling system.

At very high temperatures, a reaction between zirconium and water vapour can create hydrogen gas. This also happened at Three Mile Island, and the bubbles of very explosive hydrogen gas inside the reactor vessel caused further problems. However, the reactor containment vessel did not breach, and only relatively small amounts of radioactivity were released into the environment. The crisis ended on 1 April, but the clean-up of the plant itself took years. Today, the Unit 2 reactor is permanently shut down, and the spent fuel and the remains of the contaminated cooling water have been transported for storage elsewhere. More information on the accident can be found in U.S.NRC Backgrounder (U.S. NRC, 2009) and Collins (Collins *et al*,1982).

6.4.1.2 The nuclear reactor accident in Chernobyl, Soviet Union, 1986

On 26 April 1986 a major accident started in Unit 4 of the Chernobyl Power Complex 130 km north of Kiev, Ukraine. The reactor was a Soviet designed RBMK, boiling light water graphite moderated reactor. The RBMK design operates using slightly enriched (2 % in U-235) uranium dioxide fuel encapsulated in a zirconium alloy. The power output is 3 200 MWt or 1 000 MWe. The most important characteristics of a RBMK are the “positive void coefficient” increasing the fission reaction when the power increases counteracted by the “negative fuel coefficient” where the neutron flux reduces with increasing temperature in the fuel. At normal operating power levels the temperature effect is dominant, but if the power output decreases to 20 % of normal, the positive void coefficient makes the reactor unstable. (NEA, 2002) Another important aspect for the consequences of the accident was that RBMKs lacks a containment structure to keep radioactive substances inside the reactor building in case of a release. (IAEA, 2001b)

Unit 4 was shut down for routine maintenance on 25 April 1986. The opportunity was taken to test if cooling of the core could be maintained by emergency equipment in the event of loss of power. The personnel in charge of safety of the reactor were not informed of the test, because it was thought only to concern non-nuclear parts. As a result of this, the test personnel were not informed of the potential danger and took no safety precautions.

Several operating errors led the reactor to an unstable condition and the unforgiving design of the reactor made the situation deteriorate. At 1:23 a.m. there was a sudden power surge, increasing heat production causing a steam explosion to destroy the reactor core. A second explosion occurred two seconds later, possibly caused by hydrogen build-up. The two explosions exposed the core to the atmosphere and sent a radioactive plume 1 km into the air. Subsequently a fire started in the building of Unit 4 and adjacent buildings. 250 fire fighters were involved in the fire fighting, and by 5 a.m. the fire in the buildings were put out, but by then a fire had started in the graphite moderator. A graphite fire is much harder to control, and it took ten days of dumping various materials (both neutron-absorbing and fire-controlling) into the reactor from helicopters before it was extinguished. The destroyed reactor was later encapsulated in a concrete envelope (“sarcophagus”) to contain the radioactivity long term. (NEA, 2002)

The total release of radioactive substances was calculated in May 1986 by Soviet scientists to be roughly 1.9 EBq, excluding noble gases (Ilyin *et al*., 1987). Of this, the biomedically significant I-131 and Cs-137 were estimated to 270 PBq and 37 PBq respectively. The calculations for I-131 and Cs-137were later amended by international groups of scientists to 1760 PBq and 85 PBq, taking into account also deposition outside the Soviet Union (NEA, 2002).

In the first ten days after the accident, meteorological conditions were unstable, resulting in great variations in dispersion parameters and release directions. In summary, heavier particles were deposited no more than 100 km from the reactor. Most of Europe had some deposition, mainly of caesium. Due to wind and rain, the Nordic countries, Germany, Austria and Switzerland had the greatest deposition. The plume was detectable throughout the Northern hemisphere, but no elevated levels were detected by surveillance networks in the Southern hemisphere. (NEA, 2002)

In Pripyat, 3 km from the accident site, there lived 49 000. Within a 30 km radius of the power complex there was a population of up to 135 000. Soviet scientists have estimated that the maximum dose to members of the public has been 0.1 Gy external gamma and that the vast majority of Pripyats inhabitants probably received between 15 and 50 mGy from gamma radiation (Ilyin *et al*., 1987). For two days the inhabitants of Pripyat were advised to stay indoors with their windows closed, and iodine prophylactics were distributed. In the following days 115 000 people were evacuated, most of them have never returned. (Ilyin *et al*., 1987 and IAEA ,2001b)

During or soon after the accident 31 people died, from radiation poisoning and from the blast. (NEA, 2002 and IAEA, 2001b) 134 were treated for acute radiation syndrome. There has been a significant increase in thyroid cancers in the contaminated areas in the former Soviet Union, mostly in those who were small children at the time of the accident. Other forms of cancer have not increased, neither in personnel (about 600 000 people) involved in recovery operations, nor in the general population. Psychological effects such as anxiety, stress and depression are widespread in the affected areas in the former Soviet Union, but are not apparent in the rest of Europe. (IAEA, 2001b and NEA, 2002)

The cost of the Chernobyl accident is difficult to calculate exactly, but in Ukraine up to 7 % of the national budget is still used for coping with the consequences, and in Belarus the total spending so far is more than US $13 billion (IAEA, 2005). The European Bank for Reconstruction and Development administrates a fund for building a new sarcophagus around Unit 4, estimated to have a cost of almost US $800 million (IAEA, 2001b).

6.4.1.3 The nuclear reactor accident in Fukushima, Japan, 2011

The accident in the Fukushima nuclear plant started after a magnitude 9 earthquake caused a devastating tsunami to flow over the east coast of Japan on 11 March 2011. Since this accident happened quite recently, a complete outline of the development and consequences is not yet available. There were two nuclear plants in the Fukushima district, Fukushima Dai-ichi and Dai-ni, both operated by the electricity company TEPCO. Even though Dai-ni was also affected by the earthquake and tsunami, the most serious consequences occurred at Dai-ichi.

Fukushima Dai-ichi consisted of six boiling water reactors. At the time of the tsunami, units 1 to 3 were in operation, while units 4 to 6 were shut down for maintenance or refuelling. Unit 5 and 6 are located apart from the other units and at a higher elevation, and suffered overall less damage. In immediate response to the earthquake, reactors 1 to 3 were automatically shut down and control rods inserted. The site had a total of 13 emergency diesel power generators. At the time of the earthquake, one was undergoing maintenance; the other twelve were stared up after the earthquake, but all but one generator situated at unit six were severely damaged by the following tsunami. The generator at unit 6 continued to provide power to run the cooling and instrumentation systems at both unit 5 and 6.

All three operating reactors initially had alternative cooling systems that functioned for some hours but later failed. After this, improvised cooling system using fire extinguishing pumps and seawater were used. Units 1 to 3 had emergency batteries for powering instrumentation and control systems, but these batteries were flooded in unit 1 and 2, and flat after about 30 hours in unit 3. The emergency work was severely hampered by the lack of electricity and lighting. Communication systems also failed and roads were blocked by debris from the tsunami.

Overheating and pressure build-up in the reactor vessels caused formation of hydrogen gas, and in the days following the tsunami, several gas explosions lead to further damage. All the reactors had storage pools for used fuel, which needed systematic refilling of water. Several methods were taken into use to provide this, including dumping water from helicopters in the air, but the lack of instrumentation and very high levels of radiation on the site meant that it was difficult to determine whether they were successful.

The full consequences of the Fukushima accident have not yet been determined. The accident has not caused any loss of life as a direct cause of radiation, but large amount of radioactivity has been released into the air and sea. An area of 1 200 km^2 around the power plant site has been evacuated and 80 000 people have had to leave their homes.

A summary of the accident can be found in two IAEA reports (IAEA, 2011a-b), and it has also been extensively covered in media (BBC, 2011).

6.4.2 Criticality accidents

6.4.2.1 The criticality accident in Sarov, Russia, 1997

On 17 June 1997, a technician at the Russian Federal Nuclear Centre in Sarov was working on a criticality assembly consisting of a highly enriched uranium core and a copper casing. The technician was experienced and had worked on similar critical assemblies before, but was working alone in spite of security regulations. At one point, the technician's hand slipped, causing him to drop a piece of the casing on to the critical assembly. The system went critical, resulting in a burst of gamma and neutron radiation, exposing the technician to an estimated whole body dose of 10 Gy.

The technician immediately realised what had happened, left the room and informed his supervisors. The site was evacuated, and the exposed worker sent to hospital, where he, despite intensive care, died less than three days later. The dismantlement of the critical assembly proved difficult because of the high levels of radiation involved, but was finally completed on 24 June, using a remote controlled robot. The accident is described in an IAEA report (IAEA, 2001).

6.4.2.2 The criticality accident in Tokaimura, Japan, 1999

The Tokaimura plant was a small plant for fabrication of nuclear fuel elements, using a wet process. The plant was commissioned in 1988, and had permission to produce fuel enriched up to 20 % in U-235, however, most of the fuel produced at the plant used uranium with a much lower enrichment. At the time of the accident, the plant had, without permission from the regulatory authorities, modified its work procedures to speed up the process, and the actions that preceded the accident were not in accordance with the legally approved safety measures.

On 30 September 1999, three workers were preparing a batch of fuel for an experimental reactor, using uranium enriched to 18.8 % in U-235. This was considerably higher than the level they usually handled, but despite of this, they followed the same work procedure without calculating the risk of reaching criticality with the higher levels of U-235. The uranium in the form of uranium oxide (U_3O_8) was dissolved in nitric acid in steel buckets and then poured into a storage tank. When the level in the tank reached 40 litres of solution, corresponding to about 16 kg of uranium, criticality was reached.

When a configuration of fissile materials (like uranium) reaches criticality, a nuclear chain reaction becomes self-sustaining. This process creates large amounts of gamma and neutron radiation and generates heat. In addition to this, new radioactive elements (fission products) are created in the process. The three workers in the room received massive doses of radiation and were hospitalised. Two of them later died. Other workers at the plant, both inside and outside the building, were also exposed to a high level of radiation. A total of 119 people received radiation doses over 1 mSv.

The criticality continued for about 20 hours, but no explosion occurred. Large amounts of fission products were created, but the ventilation system in the building managed to contain most of this.

Five hours after the accident started, 161 residents in buildings within 350 meters of the facility were evacuated. Seven hour after this, people living within a radius of 10 km, around 310 000 people, were asked to stay inside as a precautionary measure. This measure was lifted after about 18 hours, and the evacuated were allowed to return home after two days. The accident is described in reports by the World Nuclear Association (WNA, 2007) and IAEA (IAEA, 1999b).

7. Scenario template and requirements

The purpose for developing a set of reference CBRN scenarios in PRACTICE is to use it in all subsequent WPs. It is important to ensure that the scenario set covers relevant scenarios for the project as a whole and that scenarios are described at a level of detail necessary from the other WP perspectives. Hence, the requirements and the scenario template were discussed with representatives for the other WPs and end-users at a workshop on 22 June 2011. This chapter presents the key requirements from other WPs and the final scenario template for development of scenarios.

7.1 Requirements for use in subsequent WPs

The key topics will be included in the scenario descriptions, *i.e*. the scenario context, type of threat compound(s), how it is dispersed, cause of the incident and immediate consequences (casualties and hazard area).

WP3 will use the set of scenarios to identify existing operational functions and practices in emergency preparedness and response. WP3 is interested in how the details are handled by responders and end-users in a cross European perspective. In addition, WP3 wishes to include the scale of event, the whole security cycle, actors, expected effects, and information on awareness in the public.

WP4 will build on the parameters from WP2 and the operational functions from WP3 to analyse possible gaps in emergency preparedness and response. Based on this, WP4 will develop the concept for the toolbox. The scenarios will also be included in the toolbox as examples. The parameters from WP2 are observables that trigger action by emergency authorities. Also it will be desirable with a possible grouping of parameters, limited number of parameters with sub-parameters, and a time line. Scenarios should also include communication lines during the response.

WP5 will develop the toolbox as outlined in WP4, thus indirectly rely on the scenarios as used and implemented in WP4.

WP6 will arrange three field exercises for which scenarios will be used. The exercises will be held in the UK, Sweden and Poland, respectively.

The UK validation exercise (tentatively June 2013) will focus on human factors and testing of the manuals for the general public developed through WP8. Tentatively, there will be 50 volunteers. The exact venue has not been decided yet, but it will be an indoor incident at a shopping mall, airport or a conference centre. One of the developed scenarios will be used, most likely a biological scenario.

The Swedish exercise (tentatively November 2013) will test the manuals and training kit developed for the first responders. Probably, several repetitions will be conducted in series in order to focus on different levels of training. A simple scenario is preferable. There are outdoor training facilities including a large field, with the possibility to use some buildings. A dirty bomb-scenario could be suitable.

The Polish full scale international exercise will be held in 2014 as part of an annual large-scale Polish exercise. The focus will be on first responders, local authorities and technical equipment, and demonstrating the toolbox created by PRACTICE. There are plans to use an abandoned city as location. The scenario will be a catastrophic scenario that also triggers international cooperation, possibly multiple smaller incidents linked together in a time span.

It was decided that the detailed planning of the scenario storyline for the exercises need to be developed by the planners in WP6. WP2 will provide scenario description and consequence assessments which will form the basis for further adaptation; storyline and exercise inject creation for the particular exercises.

WP7 will develop training kits and educational programmes for emergency response personnel. The scenarios should describe the environment quite detailed and the evolution over time of the situation. This will be used directly in WP7 in simulations.

7.2 Requirements for consequence assessments

The consequence assessments of the reference set of CBRN scenarios will focus on the likely time evolution of the scenarios. This will include calculations and estimations of the possible casualties, hazard areas and possible other damage caused by the scenario. Subsequently the emergency response patterns will be discussed based on the current situation in selected countries. Workshops with emergency personnel will be used as a tool to obtain this information.

The following topics will be addressed:

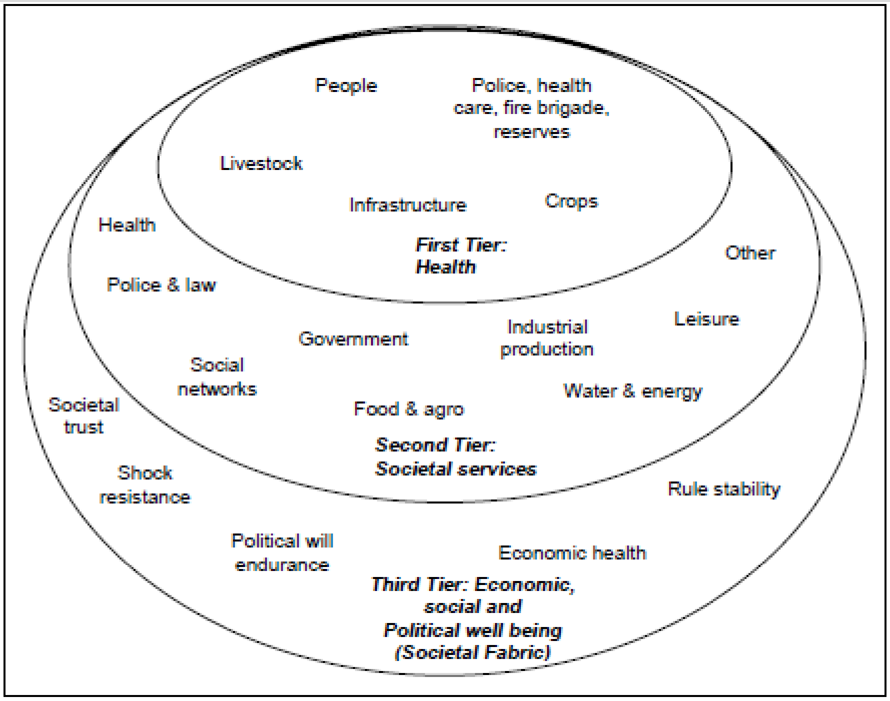
- Anticipated actions and alarms due to developing symptoms and effects. When and how will alarm be raised? Who will be called? Who will be the first on the scene?
- First responder's actions, organization and cooperation
    - o Organisational matters and share of responsibilities between the police, fire brigade, ambulance personnel. Who will be in charge at the scene?
    - o How will the responders be equipped (personal protection equipment, detectors, medical countermeasures, decontamination equipment etc)?
    - o Anticipated response times and duration of immediate crisis at the scene.
- Possible support from others, *i.e*. the civil defence, the military, non-governmental organizations. Who will be called, how and what contribution will be provided?
- Anticipated evacuation of personnel, the general public and transportation of patients to hospitals.
- When and how will the causative threat compound(s) be detected and identified?
- The medical treatment chain, *i.e*. at the scene, during transport, at hospitals.
- The authorities' crisis organization and their information and communication strategies.
- Forensic work.
- If international assistance will be sought, what type of assistance will be requested?
- The aftermath: How can the buildings and adjacent areas be restored?
- Anticipated key challenges

7.3 Scenario template

The final template for development of CBRN-scenarios in PRACTICE is given below. The text in Italics is instructions and explanations on how to fill in information. It shall be replaced by the user.

Scenario *number*	
Scenario title	
Scenario justification	
Justification for the choice of scenario. References to past real events, if any, and the inspiration for choosing this scenario. *Purpose of the scenario, i.e. illustration of certain emergency response challenges, epidemiological challenges, etc.* *Benefit for the PRACTICE project, i.e. toolbox development, validation exercises, development of training kits, etc.*	
Scenario outline	
Short description of the CBRN incident, i.e. what happens, and when, how and in what environment does the incident occur. *Short description of the context and events leading up to this scenario and the cause of the incident.*	
Cause	
Intentional (Yes/No/Both)	
Profile of actor (if intentional)	*Short description of profile of actor that is willing and capable to conduct event, including 'modi operandi'*
Description of cause	*Motive, if it is an intentional event, or cause of the accident.*
Competence and resources	*Applicable for intentional events: Needed level of competence and availability of resources (equipment and economical means)*
Threat compounds and their properties	
Threat compounds	*Name(s) and description*
Properties	*Physical and chemical properties, composition, toxicological estimates for relevant routes of exposure, minimum infectious dose, incubation period, smell, visibility, solubility, etc.*
Medical symptoms	*Type of medical symptoms, time until onset/incubation period.*
Availability	*Describe the availability of the threat compound(s). Is it easily available, frequently used, stored and transported or of very limited use thus hard to obtain? Examples of use.*
Dissemination	
Amount	*Amount dispersed*
Release mechanism	*Means of dispersion*

Equipment	*Dissemination device*
Physical state	*Vapour, liquid, solid, suspension, mixture. If applicable, particle size distribution.*
Fate	*Secondary infections (contagious or not), persistency in the environment, etc.*
Location	
Location description	*Description of the point of release and the surroundings, i.e. enclosed, semi-enclosed or open area.*
Weather	*Temperature, humidity, wind speed, precipitation, etc.*
Population at risk	*Number of people involved, those directly affected and those at risk.* *Rough description of the 'type' of population; experience with terrorist acts, ways they are prepared (informed), different ways they are suspected to react (run away, disobey orders from authorities etc.).*
Time	*Time of day, during a specific event.*
Other	*Other information that is relevant for the consequence management and challenges of the scenario.*
Indication or alert	
Announcement	*(Yes/No) From terrorist announcement, information from the intelligence services or other sources.* *Options: no announcement, announcement before the incident and/or claim/announcement after incident (when it is a terrorist act).*
Observations	*Description of direct observations.*
Detection	*Detection by instruments or humans (smell, vision, symptoms).*
Alert	*What causes the alert to be raised? How is the alert raised, and what is reported to the first responders, authorities or site personnel?*
Local safety and security measures	*Physical security measures, detection equipment, routines and procedures, etc. at the facility/on the premises.*
Possible consequences and development	
Reference time	*Definition of time zero. This should be clearly defined and recorded for example as the first call to the emergency number.*
Minutes	
Hours	
Days	

Months	
Impacts of the scenario: **The 3-tier impact model from the ASSRBCVUL project is used.**  *Figure 2.1. Model of impact areas in European society* ASSRBCVUL – Assessment of the vulnerabilities of modern societies to terrorist acts employing radiological, biological or chemical agents with the view to assist in developing preventive and suppressive crisis management strategies.	
1st order challenges *Challenges related to the direct effects of the incident, i.e. effects on the population, first responders, authorities, infrastructure and the environment that are directly caused by the attack, accident, or disease.*	
Directly affected population	
First responders Are there plans, methods, equipment, procedures and training available?	Technical measures Casualty care Organisation Communication Property Environment
Health services	
Command and control centre	
Site/building/infrastructure	

stakeholder(s)	
Other authorities	
Media	
Infrastructure	
Environment	
Authorities in other countries	
International organisations	
2nd order challenges *Challenges that indirectly cause problems or disruption for the population, the authorities and infrastructure.*	
Population	
Government	
Health services	
Police and law	
Food and water production and distribution	
Communication	
Transportation	
Energy supply	
Industry and commerce	
Leisure	
Other	
3rd order challenges *Overarching societal, political and economic challenges indirectly caused by the incident.*	
References	
Relevant literature	

The scenario”Chemical attack inside building – Sarin dispersal through ventilation system” has been used in the development of the template and is given as an example in Appendix E. The next deliverable of WP2 will be the reference set of CBRN scenarios.

8. Conclusions and further work

This report constitutes the first deliverable of WP2. The aim has been to define the framework and requirements for CBRN scenario descriptions and level of detail needed to ensure compatibility with subsequent use in other WPs. Prior to the first WP2 meeting in June 2011, PRACTICE participants shared information on existing templates, worked-through scenarios and consequence assessments, both historical events and hypothetical scenarios, and previous results. Active involvement from WP leaders, stakeholders and end-users was achieved through a workshop on 22 June 2011. All information is used as a basis for WP2.

This report lists scenarios used in previous projects, which have been made available for use in PRACTICE. Also, it summarises historical cases of CBRN terrorist events and accidents referenced to credible sources of information. Lastly, it presents the scenario template which will be used by the PRACTICE project and requirements for scenario descriptions and level of detail to ensure optimum use in subsequent WPs.

The information on previously developed scenarios, historical cases of CBRN terrorist events and accidents and the scenario template and requirements will be used as a basis for selecting and developing appropriate and representative CBRN-scenarios, which is the next task of WP2. It will also be used as background when assessing plausible consequences of these scenarios and identifying, describing and organising sets of critical event parameters and observables characterising the events, which is the third and last task of WP2.

The remaining deliverables of WP2 are:

- Reference set of CBRN scenarios covering releases of hazardous chemical (C), biological (B) and radiological (R) substances
- Consequence assessments of the selected set of reference CBRN scenarios and critical event parameters

A recommendation for future work and a possible project idea is to develop a database of CBRN incidents and existing scenarios. Such a database would be useful when planning emergency response education, training and exercises and as a basis for collecting and analysing lessons learned.

9. List of abbreviations

ASSRBCVUL	Assessment of the vulnerabilities of modern societies to terrorist acts employing radiological, biological or chemical agents with the view to assist in developing preventive and suppressive crisis management strategies
BTWC	Biological and Toxin Weapons Convention
Bq	Becquerel, (event) per second, the SI unit for radioactivity
Ci	Curie, an older unit for radioactivity, still used in USA
CIE Toolkit	Chemical Incidents Emergencies Toolkit
CBRN	Chemical (C), Biological (B), Radiological (R), Nuclear (N)
Co-60	Cobalt-60, a radioactive isotope
Cs-137	Caesium-137, a radioactive isotope
CWC	Chemical Weapons Convention
Ebq	Exabecquerel, 10^{18} Bq
FBI	Federal Bureau of Investigation (USA)
FFI	Forsvarets forskningsinstitutt (*Eng.* Norwegian Defence Research Establishment)
FOI	Totalförsvarets forskningsinstitut (*Eng*. Swedish Defence Research Agency)
GBq	Gigabecquerel, 10^{9} Bq
GSCT	Generic Scenarios on Release of Chemicals by Terrorists
HAZMAT	The Jefferson County Hazardous Materials Team (USA)
I-131	Iodine-131, a radioactive isotope
IAEA	International Atomic Energy Agency
IMPACT	Innovative Measures for the Protection Against CBRN Terrorism
Ir-192	Iridium-192, a radioactive isotope
MASH	Mass casualties and health care following the release of toxic chemicals and radioactive material
mGy	Milligray, 10^{-3} gray, a unit for radiation dose
mGy/h	Milligray per hour, a unit for radiation dose rate
mSv	Millisievert, 10^{-3} sievert, a unit for radiation dose
mSv/h	Millisievert per hour, a unit for radiation dose rate
MIC	Methyl isocyanate
MSB	Myndigheten för samhällsskydd och beredskap (*Eng.* Swedish Civil Contingencies Agency)
MW_e	Megawatt electric
MW_t	Megawatt thermal
NTSB	National Transportation Safety Board (USA)
OPCW	Organisation for the Prohibition of Chemical Weapons

PBq	Petabecquerel, 10^{15} Bq
PRACTICE	Preparedness and Resilience Against CBRN Terrorism using Integrated Concepts and Equipment
PWR	Pressurized water reactor
RBMK	“Reaktor bolshoy moshchnosti kanalniy” or high power channel-type reactor
RMC	Rajneesh Medical Cooperation
SARS	Severe acute respiratory syndrome
SGSP	Main School of Fire Service
TBq	Terabecquerel, 10^{12} Bq
TCDD	Tetrachlorodibenzoparadioxin
TIC	Toxic Industrial Chemicals
TNO	The Netherlands Organisation for Applied Research
U-235	Uranium-235, a radioactive and fissile isotope
U_3O_8	A mix of different uranium oxides, with the average of three uranium and eight oxygen atoms
UCIL	Union Carbide India Limited (UCIL), pesticide plant
USAMRIID	United States Army medical Research Institute of Infectious Diseases
USPIS	United States Postal Inspection Service
WHO	World Health Organization
WNA	World Nuclear Association
WP	Work Package

10. Literature

Alibek K., Handelman S. (2000), “Biohazard: The Chilling True Story of the Largest Covert Biological Weapons Program in the World - Told from Inside by the Man Who Ran it”, Delta, ISBN 0-385-33496-6.

Aristatek (2007), ”Chlorine Rail Car Accident, Macdona TC”, August 2007, (http://www.aristatek.com/newsletter/0708august/TechSpeak.pdf).

Balkau F. (2010), “Learning from Baia Mare”, Environment and Poverty Times, 03/2005, (http://www.grida.no/files/publications/environment-times/kobetimes_0405.pdf).

BBC (2000), “Romania’s poison dump”, May 2000, (http://news.bbc.co.uk/2/hi/programmes/correspondent/755780.stm).

BBC (2011), “Tepco faces shareholder wrath following nuclear crisis” 28 June 2011, (http://www.bbc.co.uk/news/business-13938774).

Bourdeau P. and Green G. (1989), “The Assessment and Control of Chemical Accidents” in Methods for Assessing and Reducing Injury from Chemical Accidents, SCOPE, Published by John Wiley & Sons Ltd., (http://dge.stanford.edu/SCOPE/SCOPE_40/SCOPE_40_1.2_Assessment_11-44.pdf).

Brannmannen (2002), ”Eksplosjon i ammoniakktank”, Nr 4, Available in Norwegian, (http://arkiv.brannmannen.no/?cid=42&aid=45429#cid=42&aid=45429).

Broughton, Edward (2005), “The Bhopal disaster and its aftermath: a review”, Environmental Health: A Global Access Science Source, 4:6, (http://www.ehjournal.net/content/4/1/6).

BTWC (Biological and Toxin Weapons Convention) (1972), Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction, 10 April 1972, Entry into force: 26 March 1975, (http://www.opbw.org/).

Caragliano, Simona and Davide Manca (2007), “Emergency Management and Land Use Planning in Industrial Hazardous Areas: Learning from an Italian Experience”, Journal of Contingencies and Crisis Management, Volume 15, Nr 4, December 2007, (http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1033580).

Cassel G., Norlander L., Olofsson G., Svensson I. (2005), “A representative set of planning scenarios”, Innovative Measures for the Protection Against CBRN Terrorism (IMPACT) WP100, deliverable D100.1, Swedish Defence Research Agency (FOI), EU RESTRICTED.

Cassel G., Andersson Å., Burman J., Berglind R., Eriksson H., Holst J., and Persson S. (2007), “Development of Generic Scenarios for Release of Chemicals by Terrorists (GSCT)”, FOI-R—2272-SE, ISSN 1650-1942, Swedish defence Agency (FOI), June 2007.

Cassel G., Eriksson H., Sandström B. (2008), “Mass-casualties and health care following the release of toxic chemicals or radioactive materials (MASH)”, Work Package (WP) 4 deliverable, “Scenarios”, Swedish Defence Research Agency (FOI).

Cassel G., Sandström B., Norlander L., Thorstensson M., and Eriksson H. (2011) “Exercise Card Concept. Exercise Director Instructions and Scenarios”, Chemical Incidents Emergencies Toolkit, Work Package 6 deliverable, Swedish Defence Research Agency (FOI).

CDC (Centers for Disease Control and Prevention) (2010), “The 2009 H1N1 Pandemic: Summary Highlights, April 2009-April 2010”, 16 June 2010, (http://www.cdc.gov/h1n1flu/cdcresponse.htm).

CDC (Centers for Disease Control and Prevention) (2011), Severe Acute Respiratory Syndrome (SARS), (http://www.cdc.gov/ncidod/sars/).

CNN (2011), “Scientific review reaches no conclusion on source of anthrax”, (http://www.cnn.com/2011/US/02/15/anthrax.source/).

Collins E.D. (1982), Oak Ridge National Laboratory: ”The Three Mile Island Accident and Post-Accident Recovery – What did we Learn?” (Paper presented at the Meeting of the American Society of Certified Engineering Technicians Oak Ridge Tennessee, May 13, 1982.) (http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/14/719/14719499.pdf).

CSB (2002), “Chlorine Release”, U.S. Chemical Safety and Hazard Investigation Report Board (CSB), DPC Enterprises, L.P. Festus, Missouri, Report no. 2002-04-I-MO, May 2003. (http://www.csb.gov/assets/document/DPC_Report.pdf).

CWC (Chemical Weapons Convention) (1993). Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on their Destruction, 13 January 1993. Entry into force: 29. April 1997. (http://www.opcw.org/).

Department of Justice (2010), “Amerithrax investigative summary”, Friday February 19, 2010. (http://www.justice.gov/amerithrax/).

Department of Justice (2011), “FBI and Justice Department Response to NAS Review of Scientific Approaches Used During the Investigation of the 2001 Anthrax Letters”, Press Release, 15 February 2011. (http://www.fbi.gov/news/pressrel/press-releases/fbi-and-justice-department-response-to-nas-review-of-scientific-approaches-used-during-the-investigation-of-the-2001-anthrax-letters).

Dorison A. (2001), “The Industrial Disaster of Toulouse”, Ecole des Mines d’Alès, September 2001. Dorison is the Director of the Ecole des Mines d’Alès, a French Institute for Engineering and Applied Science under the tutelage of the French Ministry in charge of Industry).

DSB (2002), ”Erfaringer fra ammoniakkulykken på Kjøndal gård i Larvik”, The Norwegian Directorate for Civil Protection and Emergency Planning (DSB) (In Norwegian).

Dunai, Marton (2010), “Toxic Hungarian sludge spill reaches River Danube”, Reuters, October 2010 (http://in.reuters.com/article/2010/10/07/us-hungary-spill-idINTRE69415O20101007).

The Economist (2010), “Hungary’s toxic sludge: Waltzing with disaster”, October 2010 (http://www.economist.com/node/17259027).

Endregard M., Reif B. A. P., Vik T., Busmundrud O., “Consequence assessment of indoor dispersion of sarin—A hypothetical scenario”, *Journal of Hazardous Materials* **176** (2010) 381–388.

Enzler, S. M. (2006), “The Baia Mare Cyanid Spill”, Environmental disasters, Lenntech BV, The Netherlands. (http://www.lenntech.com/environmental-disasters.htm).

Eriksson H., Persson S. Å., Berglind R., Cassel G. (2007), “Togurspårningen i Kungsbacka 2005-02-28. En genomgång av beredskapen om det som inte hände - ändå hade hänt”, Swedish Defence Research Agency (FOI), Report, R-SE, 2007. (Available in Swedish.)

EU Council Framework Decision (2002). “COUNCIL FRAMEWORK DECISION of 13 June 2002 on combating terrorism”. 2002/475/JHA.

European Commission (2010), “Chemical Accidents (Seveso 2) – Prevention, Preparedness and Response”. European Commission – Environment – Chemical Accidents (Seveso II). December 2010, (http://ec.europa.eu/environment/seveso/index.htm).

FOI (2006). ”Building Crisis Management Capacity in the EU” (FOI 2006). FOI-r-1920-SE, (http://www.foi.se/upload/ASEK/foir1920_building_crisis_management.pdf).

General Inspectorate for the Environment (2001), “REPORT to the Minister for Regional Development and the Environment on the accident that occurred at the Grande Paroisse company factory in TOULOUSE on 21st September 2001”, Paris, 23 October 2001. Ministry for Regional Development and the Environment.

The Hindu (2010a), “Scrap dealer, workers suffers burns from radiation exposure”, The Hindu, Chennai, 8 April 2010.

The Hindu (2010b), “800 Shops in west Delhi scrap marked scanned”, The Hindu, Chennai, 15 April 2010.

The Hindu (2010c),“DU staff ‘miscalculated’ Cobalt 60’s radioactive time” , The Hindu, Chennai, 29 April 2010.

The Hindu (2010d), “Radiation response team recovers 16 cobalt pencils from Mayapuri”, The Hindu, Chennai, 5 May 2010.

Homeland Security Council (2004), “Planning Scenarios, Executive Summaries”, July 2004, http://www.globalsecurity.org/security/library/report/2004/hscplanning-scenarios-jul04 exec-sum.pdf (accessed 6 August 2008).

IAEA (1988), STI/PUB/815, ”The Radiological Accident in Goiânia”, IAEA, Vienna, 1988, (http://www-pub.iaea.org/mtcd/publications/pdf/pub815_web.pdf).

IAEA (1990), “The Radiological Accident in San Salvador”, IAEA, Vienna, 1990, (http://www-pub.iaea.org/MTCD/publications/PDF/Pub847_web.pdf).

IAEA (1993), “The Radiological Accident in Soreq”, IAEA, Vienna, 1993, (http://www-pub.iaea.org/MTCD/publications/PDF/Pub925_web.pdf).

IAEA (1996), “Chernobyl – Ten years after”, Gonzáles, A.J., IAEA Bulletin, (http://www.iaea.org/publications/magazines/bulletin/bull383/gonzales.html).

IAEA (1998), “The Radiological Accident in Tammiku”, IAEA, Vienna, 1998, (http://www-pub.iaea.org/MTCD/publications/PDF/Pub1053_web.pdf).

IAEA (1999a), “The Radiological Accident in Tbilisi”, IAEA, Vienna, 1999, (http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/29/064/29064267.pdf).

IAEA (1999b): “Report on the preliminary fact finding mission following the accident at the nuclear fuel processing facility in Tokaimura, Japan”, IAEA, Vienna, 1999, (http://www-pub.iaea.org/MTCD/publications/PDF/TOAC_web.pdf).

IAEA (2000a), “The Radiological Accident in Yanango” IAEA, Vienna, 2000, (http://www-pub.iaea.org/MTCD/publications/PDF/Pub1101_web.pdf).

IAEA (2000b), “The Radiological Accident in Istanbul”, IAEA, Vienna, 2000, (http://www-pub.iaea.org/MTCD/publications/PDF/Pub1102_web.pdf).

IAEA (2001), “The Criticality Accident in Sarov”, IAEA, Vienna 2001, (http://www-pub.iaea.org/mtcd/publications/pdf/pub1106_scr.pdf).

IAEA (2001b), “Frequently asked Chernobyl questions”, (http://www.iaea.org/newscenter/features/chernobyl-15/cherno-faq.shtml).

IAEA (2002a), IAEA Press release 2002/09, “Inadequate control of world’s radioactive sources”, (www.iaea.org/newscenter/pressreleases/2002/prn0209.shtml).

IAEA (2002b), “The Radiological Accident in Gilan”, IAEA, Vienna, 2002, (http://www-pub.iaea.org/MTCD/publications/PDF/Pub1123_scr.pdf).

IAEA (2002c), “The Radiological Accident in Samut Prakarn”, IAEA, Vienna, 2002. (http://www-pub.iaea.org/MTCD/publications/PDF/Pub1124_scr.pdf)

IAEA (2004), “The Radiological Accident in Cochabamba”, IAEA, Vienna, 2004, (http://www-pub.iaea.org/MTCD/publications/PDF/Pub1199_web.pdf)

IAEA (2005), “Chernobyl’s legacy: Health, Environmental and socio-economic impacts”, (http://www.iaea.org/publications/booklets/chernobyl/chernobyl.pdf).

IAEA (2009), “The Radiological Accident in Nueva Aldea”, IAEA, Vienna, 2009, (http://www-pub.iaea.org/MTCD/publications/PDF/Pub1389_web.pdf).

IAEA (2011a), “IAEA International fact finding Expert Mission of the Nuclear Accident Following the great East Japan Earthquake and Tsunami”, preliminary summary , IAEA, Vienna, 2011, (http://www.iaea.org/newscenter/focus/fukushima/missionsummary010611.pdf).

IAEA (2011b), “IAEA International fact finding Expert Mission of the Fukushima Dai ichi NPP Accident Following the great East Japan Earthquake and Tsunami”, IAEA, Vienna, 2011 (http://www pub.iaea.org/MTCD/Meetings/PDFplus/2011/cn200/documentation/cn200_Final-Fukushima-Mission_Report.pdf).

Ilyin, L.A. and Pavlovskij, O.A. (1987) “Radiological consequences of the Chernobly accident in the Soviet Union and measures taken to mitigate their impact”, IAEA bulletin 4/1987.

Institute of Occupational Safety (1998), ”Radiological incident in Spain and its influence in Slovenia”, Institute of Occupational Safety, Slovenia, (http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/30/017/30017644.pdf).

Ivansson, G. (2005), “Tåg med 770 ton klor spårade ur Kungsbacka. Unik och riskfylld bärgning”, Sirenen, 03/2005. Available in Swedish, (http://www.tjugofyra7.se/Global/Sirenen/Sirenen_2005_Nr_03.pdf).

Kletz, Trevor (2001), “Learning from Accidents”, Third Edition, Gulf Professional Publishing.

Leeuw, M.W. (Project Coordinator) (2007), “Deliverable #9. Final report”, Assessment of the vulnerabilities of modern societies to terrorist acts employing radiological, biological or chemical agents with the view to assist in developing preventive and suppressive crisis management strategies (ASSRBCVUL), 2007-05-04, EU Restricted.

McLauchlin J., Grant K. A., Little C. L. (2006), Journal of Public Health, Vol. 28, No. 4, pp. 337–342, (http://jpubhealth.oxfordjournals.org/content/28/4/337.full.pdf).

Meselson, M., Guillemin, J., Hugh-Jones, M., Langmuir, A., Popova, I., Shelokov, A., Yampolskaya, O. (1994), “The Sverdlovsk Anthrax Outbreak of 1979”, Science, 266, 1202 – 1208.

Mitchell J. T., Edmonds A. S., Cutter S. L., Schmidtlein M., McCarn R., Hodgson M. E., Duhè S. (2005), ”Evacuation Behaviour in Response to the Graniteville, South Carolina, Chlorine Spill”, Quick Response Research Report 178, University of South California, (http://www.colorado.edu/hazards/research/qr/qr178/qr178.pdf).

MSB (Swedish Civil Contingencies Agency, Myndigheten för samhällsskydd och beredskap) (2010), “Scenarios for Threat and Risk Assessments. Collaboration Area for Hazardous Substances” (In swedish: Hot- och riskvärderade scenarier. Samverkansområdet Farliga ämnen), ISBN 978-91-7383-082-9, (www.msb.se).

National Board of Health and Welfare (In Swedish: Socialstyrelsen) (2000), “Chemical Accidents and Disasters”, Medical Care, Planning Guidance, (http://www.socialstyrelsen.se/Lists/Artikelkatalog/Attachments/11683/2000-0-16_0000016.pdf).

National Research Council (2011), “Review of the Scientific Approaches Used During the FBI's Investigation of the 2001 Bacillus Anthracis Mailings”, ISBN-10: 0-309-18719-2.

NTSB (National Transportation Safety Board) (2004), “Derailment of Canadian Pacific Railway Freight Train 292-16 and subsequent release of anhydrous ammonia near Minot, North Dakota January 18, 2002”, Railroad Accident Report, NTSB/RAR-04/01, PB2004-916301, Washington DC, March 9, 2004.

Nuclear Energy Agency (2002), “Chernobyl – Assessment of radiological and health impacts. 2002 Update of Chernobyl: Ten years on”.

Socialstyrelsen, Stockholms läns landsting (2006), Projekt Storstad. En sammanställning av Stockholms läns katastrofmedicinska förmåga (Project Big City – A Summary of Disaster Medical Resources in Stockholm County) (In Swedish), Artikelnr 2006-124-7, (www.socialstyrelsen.se).

Tu, Anthony T. (2002), “Chemical Terrorism: Horrors in Tokyo Subway and Matsumoto City”, Alaken, Inc.Fort Collins, Colorado, ISBN 1-880293-10-2.

Tu, Anthony T. (2007), “Toxicological and chemical aspects of sarin terrorism in Japan in 1994 and 1995”, Toxin Reviews, 26, 231-274.

Tucker, Jonathan B. (Editor) (2001), “Toxic Terror, Assessing Terrorist Use of Chemical and Biological Weapons”, MIT Press.

Tweeddale, Mark (2003), “Managing Risk and Reliability of Process Plants”, Gulf Professional Publishing.

United States Department of Labor (2011). “Toxic Industrial Chemicals (TICs)”. 05/11/2011. Occupation Safety & Health Administration, (http://www.osha.gov/SLTC/emergencypreparedness/guides/chemical.html).

U.S.NRC Backgrounder (2009), “Three Mile Island Accident”, August 2009, (http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/3mile-isle.pdf).

WHO (World Health Organization) (2010), “What is the pandemic (H1N1) 2009 virus?”, 24 February 2010, (http://www.who.int/csr/disease/swineflu/frequently_asked_questions/about_disease/en/index.html).

WHO (World Health Organization) (2011a), “Health topics - Severe acute respiratory syndrome”, (http://www.who.int/topics/sars/en/).

WHO (World Health Organization) (2011b), “Global Alert and Response (GAR) Situation Updates – SARS”, (http://www.who.int/csr/sars/archive/en/).

Willey, Ronald J., Dennis C. Hendershot and Scott Berger (2006), ”The Accident in Bhopal: Observations 20 Years Later”, American Institute of Chemical Engineers, (http://www.aiche.org/uploadedFiles/CCPS/About/Bhopal20YearsLater.pdf).

Wilson, David C. (1982), “Lessons from Seveso”, Chemistry in Britain, July 1982, (http://www.davidcwilson.com/Seveso.pdf).

World Nuclear Association (2007), “Tokaimura Criticaliy accident”, July 2007, (http://www.world-nuclear.org/info/inf37.html).

I Appendix A Chemical accidents

Country, Place, Year	Chemical Accident	Substance	Consequences	Reference
Italy, Seveso, 1976.	Accident at a chemical manufacturing plant. A reactor was overheated, and when a burst disc ruptured, part of the contents of the vessel was released.	2,3,7,8-Tetrachlorodibenzo paradioxin (TCDD).	0 deaths, 2000 people treated for dioxin poisoning.	**1.** Caragliano, Simona and Davide Manca (2007). “Emergency Management and Land Use Planning in Industrial Hazardous Areas: Learning from an Italian Experience”. *Journal of Contingencies and Crisis Management*. Volume 15, Number 4, December 2007. **2.** Kletz, Trevor (2001:103). *Learning from Accidents*. Third Edition. Gulf Professional Publishing. **3.** Wilson, David C. (1982). “Lessons from Seveso”. *Chemistry in Britain*, July 1982.
Spain, San Carlos, 1978.	A road tanker overfilled with propylene gas exploded and caused a fire at a camping site.	Propylene.	Approximately 200 deaths, about 100 injuries.	Murray and Goodfellow (2002:6). “Mass casualty chemical incidents – towards guidance for public health management”. *Public Health* Jan; 116 (1),2-14.
Mexico, Montana, 1981.	Train derailment. A high speed goods train tried to avoid a passenger train at the train station when the train derailed.	Chlorine. Four tank wagons contained chlorine.	28 deaths, 1000 injuries.	Murray and Goodfellow (2002:5). “Mass casualty chemical incidents – towards guidance for public health management”. *Public Health* Jan; 116 (1),2-14.
India, Bhopal, 1984.	Gas leak disaster at a pesticide plant. Water in the storage tanks caused an exothermal reaction releasing poisoning gas which opened the safety valves.	Methyl isocyanate (MIC).	2500 deaths, approximately 200 000 injuries.	**1.** Socialstyrelsen; the National Board of Health and Welfare (2000:8). “Chemical Accidents and Disasters”. Medical Care. Planning Guidance. **2.** Willey, Ronald J., Dennis C. Hendershot and Scott Berger (2006). ”The Accident in Bhopal: Observations 20 Years Later”. American Institute of Chemical Engineers. Unpublished. **3.** Broughton, Edward (2005). “The Bhopal disaster and its aftermath: a review”. Environmental Health: A Global Access Science Source, 4:6.
Romania, Baia Mare, 2000.	A tailing dam overflowed and released chemicals into a river nearby.	Cyanide, but also copper, zink and lead.	0 deaths. Up to 100 people were treated in hospital after eating polluted fish.	**1.** Enzler, S. M (2006). “Environmental disasters”. Lenntech BV. The Netherlands. **2.** Balkau, Fritz (2005). “Learning from Baia Mare”. Environment & Poverty Times, 03/2005.

France, Toulouse, 2001.	Ammonium nitrate explosion in a facility producing fertilizers.	Ammonium Nitrate. (Nearby facilities stored ammonia and chlorine.)	30 deaths, 2500 injuries.	Dorison, Alain. "The Industrial Disaster of Toulouse (September 2001)". *Ecole des Mines d'Alès.*
USA, Minot, 2002.	Train derailment. Five tanker cars ruptured when a freight train derailed. About 338 tonnes of anhydrous ammonia were released immediately, while 170 tonnes were released during the next five days.	Anhydrous ammonia.	1 death, 11 seriously injured, 322 light injured.	NTSB (National Transportation Safety Board) (2004), "Derailment of Canadian Pacific Railway Freight Train 292-16 and subsequent release of anhydrous ammonia near Minot, North Dakota January 18, 2002", Railroad Accident Report, NTSB/RAR-04/01, PB2004-916301, Washington DC, March 9, 2004.
USA, Festus, 2002.	Rail Car Accident. Liquefied chlorine was transferred from a tank car to a facility when the hose used to transfer the chlorine burst. Deficiencies in the emergency shutdown systems and in the emergency response plan.	Chlorine (24 tonnes)	0 deaths, 69 injuries.	U.S. Chemical Safety and Hazard Investigation Report Board (2002:30-31). "Chlorine Release". DPC Enterprises, L.P. Festus, Missouri. Report no. 2002-04-I-MO. May 2003.
Norway, Kjøndal, 2002.	Explosion in an overfilled ammonia tank due to temperature rise and increased pressure inside the tank.	Ammonia.	1 death, 9 injuries.	The Norwegian Directorate for Civil Protection and Emergency (2002). "Erfaringer fra ammoniakkulykken på Kjøndal gård i Larvik". (To the Contact Group for Emergency Preparedness and Weapons of Mass Destruction)
Norway, Lillestrøm, 2002.	Train collision at a railway station. A train containing propane collided into a parked locomotive at the railway station.	Condensed propane.	2000 people were evacuated.	DSB (2005)."Håndtering av store hendelser og potensiell aldring i kritiske infrastrukturer". Nasjonal sårbarhets- og beredskapsrapport for 2005. NSBR-05.
USA, Macdona TX, 2004.	Rail car accident. Four locomotives and 35 railcars derailed when two trains collided.	Chlorine (60 tonnes), but also urea fertilizer and diesel fuel.	3 deaths, 43 injuries.	National Transportation Safety Board (2006). "Collision of Union Pacific Railroad Train MHOTU-23 With BNSF Railway Company Train MEAP-TUL-126-D With Subsequent Derailment and Hazardous Materials Release Macdona, Texas June 28, 2004". *Railroad Accident Report*. NTSB/RAR-06/03

USA, Graniteville, 2005.	Rail car accident. A train containing chlorine collided into a parked locomotive.	Chlorine.	9 deaths.	Mitchell, Jerry T. *et al*. (2005). ”Evacuation Behaviour in Response to the Graniteville, South Carolina, Chlorine Spill”. University of South California.
Sweden, Kungsbacka, 2005.	A goods-train derailed. The accident occurred due to a failure in the attempts to stop when turning out on a blind track to await a meeting train. The train contained 12 tank wagons, each of them carrying 65 tonnes of chlorine.	Chlorine. The train contained 12 tank wagons, each of them carrying 65 tonnes of chlorine.	No injuries, but the consequences could have been far worse.	**1.** Ivansson, G (2005).”Tåg med 770 ton klor spårade ur Kungsbacka. Unik och riskfylld bärgning”. Sirenen Nr. 3. 2005 **2.** Eriksson, H, Persson, S-V, Berglind, R, Cassel, G (2007). “Togurspårningen i Kungsbacka 2005-02-28. En genomgång av beredskapen om det som inte hände - ändå hade hänt”. FOI report, R-SE, 2007
Hungary, Ajka, 2010.	Toxic red sludge spill from an aluminum plant reached a river in Hungary. The river flows through six European countries.	Aluminum.	9 deaths, 150 injuries.	**1.** The Economist (2010). “Hungary’s toxic sludge. Waltzing with disaster”. October 16th 2010. **2.** Dunai, Marton (2010). “Toxic Hungarian sludge spill reaches River Danube”. Reuters.

II Appendix B Biological accidents and natural outbreaks

Country, place, year	Biological accidents and natural outbreaks	Substance	Consequences	Reference
The Soviet Union, Sverdlovsk, 1979.	Outbreak of anthrax at a military microbiology facility. The accident was caused by a missing filter in an exhaust pipe, where the anthrax cultures were dried to produce anthrax powder which can be dispersed as aerosols. The filter had been removed due to clogging and not replaced.	Anthrax	66 deaths. Unknown how many people fell ill.	1. Alibek K., Handelman S. (2000), "Biohazard: The Chilling True Story of the Largest Covert Biological Weapons Program in the World - Told from Inside by the Man Who Ran it", Delta, ISBN 0-385-33496-6. 2. Meselson, M., Guillemin, J., Hugh-Jones, M., Langmuir, A., Popova, I., Shelokov, A., Yampolskaya, O. (1994), "The Sverdlovsk Anthrax Outbreak of 1979", Science, 266, 1202 – 1208.
The United Kingdom, 1989-2005.	Caused by ingestions of neurotoxin produced as a result of the growth of the bacterium *Clostridium botulinum* in foods before consumption.	Food-borne botulism	Totally six incidents consisting of 33 cases with 3 deaths.	McLauchlin J., Grant K. A., Little C. L. (2006), Journal of Public Health, Vol. 28, No. 4, pp. 337–342, http://jpubhealth.oxfordjournals.org/content/28/4/337.full.pdf
Asia, North America, South America, Europe, 2003.	A viral respiratory disease caused by a coronavirus. The virus spread by close person-to-person contact.	Severe acute respiratory syndrome (SARS).	774 deaths, 8 098 people became sick.	**1.** CDC (Centers for Disease Control and Prevention) (2011), Severe Acute Respiratory Syndrome (SARS), http://www.cdc.gov/ncidod/sars/ **2.** WHO (World Health Organization) (2011a), "Health topics - Severe acute respiratory syndrome", http://www.who.int/topics/sars/en/ **3.** WHO (World Health Organization) (2011b), "Global Alert and Response (GAR) Situation Updates – SARS", http://www.who.int/csr/sars/archive/en/
Worldwide, 2009.	The H1N1 2009 virus, a virus new to humans, was first detected in California in April 2009. The influenza virus spread rapidly around the world, and on June 11, 2009, WHO declared a global pandemic.	H1N1 virus.	Uncertainty regarding the total number of casualties. More than 16,000 deaths according to WHO (per February 2010).	CDC (Centers for Disease Control and Prevention) (2010), "The 2009 H1N1 Pandemic: Summary Highlights, April 2009-April 2010", 16 June 2010, http://www.cdc.gov/h1n1flu/cdcresponse.htm

III Appendix C Radiological accidents

Country, place, year	Type of incident	Radiation source	Consequences	References
Soviet, Southern Ural, 1957	Explosion in reprocessing plant(?)	Fission products, 2 MCi/7400 TBq Main problem Sr-90	10000 persons evacuated from an area up to 150 km from the plant, 60.000 ha. Average dose max 1,5 Sv from internal 0,17 Sv external	IAEA INFCIRC/368 28 July 1989, "Report on a Radiological Accident in the Southern Urals on 29 September 1957"
Brazil, Goiânia , 1987	Orphan source	Therapy source 50,9 TBq Cs-137	External and internal exposure 4 dead, 28 local radiation damage 600 body scan 112.000 contamination scan, 249 real. >4 Gy to eight persons, none over 7 Gy, >1 Gy for 21 persons Medical personnel received a collective dose under 5 mSv during treatment	1. IAEA, STI/PUB/815, "The radiological accident in Goiânia", 1988, ISBN 92-0-129088-8 2. "How the radiological accident of Goiânia was initially determined", W.M.Ferreira, Comissao Nacional de Energia Nuclear, Distrito de Goiania — DIGOI, Goiânia, Goias 3. IAEA TECDOC-1009, "Dosimetric and medical aspects of the radiological accident in Goiânia in 1987"
El Salvador, San Salvador, 1990	Work related	Sterilization source 0,66 PBq Co-60	External exposure 1 dead, 2 ill	IAEA, STI/PUB/847, "The radiological accident in San Salvador", 1990,ISBN 92-0-129090-X
Israel, Soreq, 1990	Work related	Sterilization source 12,6 PBq Co-60	External exposure 1 dead	IAE, STI/PUB/925, "The radiological accident in Soreq, 1993, ISBN 92-0-101693-X
Estonia, Tammiku, 1994	Orphan sources	Industrial sources 150 GBq-7 TBq Cs-137 and 1,6 TBq Cs-137	External exposure 1 dead, 5 ill 15 examined	IAEA, STI/PUB/1053, "The radiological accident in Tammiku", 1998, ISBN 92-0-100698-5
Czech Republic, 1996	Orphan source	Sterilization source, 1,6 TBq Co-60 ≈ 400 mGy/h @ 0,2m	Doses were calculated, none over 1 mSv	D. Drabova, J. Matzner and Z. Prouza, "Incident involving radioactive material in steel scrap", IRPA Regional Symposium Radiation Protection in Neighbouring Countries of Central Europe. Prague. 8-12 Sept1997
Iran, Gilan, 1996	Orphan source	Industrial source 185 GBq Ir-192	One exposed person (3-4 Gy), radiation sickness, but survived, local radiation damage 600 workers had blood work checked	IAEA, STI/PUB/1123, "The radiological accident in Gilan", 2002, ISBN 92–0–110502–9
Venezuela, 1997	Work related	Well logging source, 666 GBq Am-241 ≈ 0,4 mSv	No doses over 1 mSv, 12 workers medical examination, no serious	IAEA-CN-70/44, "Radiation incident in oil well logging", J.A. Lozada, Director de

		γ and 0,45 mSv/h n @ 1m	health consequences found.	Asuntos Nucleares, Ministerio de Energia y Minas, Caracas, Venezuela, 1997
Georgia, Tblisi, 1997	Orphan sources	Several training sources Cs-137 (0,2-164 GBq)	Soldiers externally exposed over time. Not possible to calculate doses, but nine persons received local radiation damage	IAEA-CN-70/90, S. Abramidze, N. Katamadze, Z. Lomtadze, R.Cruz Suarez, A.V. Bilbao Alfonso, " The radiological accident in Tbilisi", 1997
Spain, Algeciras, 1998	Scrap smelting, orphan source	8-80 Ci Cs-137	Airborne release over borders. Not detected in Spain, 1 mBq/m3 measured in Slovenia. Calculated average dose by inhalation under 1 nSv	P. Jovanovič, "Radiological incident in Spain and its influence in Slovenia", 1999, Institute of Occupational Safety, Ljubljana, Slovenia
Turkey, Istanbul, 1998	Orphan source	Therapy source 2,3 TBq Co-60	External exposure 18 hospitalized 404 examined	IAEA, STI/PUB/1102, "The radiological accident in Istanbul", 2000, ISBN 92-0-101400-7
Peru, Yanango, 1999	Work related	Industrial source 1,4 TBq Ir-192	1 seriously damaged, 2 lighter damages	IAEA, STI/PUB/1101, "The radiological accident in Yanango", 2000, ISBN 92-0-101500-3
Thailand, Samut Prakarn, 2000	Orphan source	Therapy source 15,7 TBq Co-60	External exposure 10 persons examined 3 treated	IAEA, STI/PUB/1024, " The radiological accident in Samut Prakarn", 2002, ISBN 92–0–110902–4
Bolivia, Cochabamba, 2002	Work related	Industrial source 0,67 TBq Ir-192	4 workers (~1 Gy) and 55 bus passengers (0,02-3 Gy) No observed health damage	IAEA, STI/PUB/1199, " The radiological accident in Cochabamba", 2004, ISBN 92–0–107604–5
Chile, Nueva Aldea, 2005	Work related	Industrial source 3,33 TBq Ir-192	External exposure 190 examined 3 hospitalized	IAEA, STI/PUB/1389, " The radiological accident in Nueva Aldea", 2009, ISBN 978–92–0–103009–2

IV Appendix D Nuclear accidents

Country, place, year	Type of incident	Radiation source	Consequences	Reference
USA, Three Mile Island , 1979	Loss of coolant and partial meltdown	Release of noble gases	Small health consequences	1. U.S.NRC Backgrounder, “Three Mile Island Accident”, 2009
Soviet, Chernobyl, 1986	Uncontrolled chain reaction, explosion and fire	Release of fission products		Nuclear Energy Agency, “CHERNOBYL - Assessment of Radiological and Health Impacts, 2002 Update of Chernobyl: Ten Years On”
Russia, Sarov, 1997	Criticality incident	External neutron radiation	One dead within 3 days	IAEA , STI/PUB/1106, “The criticality accident in Sarov”, 2001, ISBN 92–0–100101–0
Japan, Tokaimura, 1999	Criticality incident	External neutron and gamma radiation Release of noble gases and iodine	2 dead, one ill, 119 exposed, 27 high doses. 161 persons inside 350 m evacuated for two days	1. World Nuclear Association, “Tokaimura Criticality Accident”, 2007 2. IAEA, “Report on the preliminary fact finding mission following the accident at the nuclear fuel processing facility in Tokaimura, Japan”, 1999
Japan, Fukushima, 2011	Loss of coolant	Release of fission products	No direct casualties. Consequences not finally determined	“IAEA international fact finding expert mission of the nuclear accident following the great East Japan earthquake and Tsunami”, Tokyo, Fukushima Dai-ichi NPP, Fukushima Dai-ni NPP and Tokai NPP, Japan 24 May- 1 June 2011 Preliminary Summary
All incidents globally	Criticality incidents: 37 in research reactors 22 in fuel fabrication	External neutron and gamma radiation	Total of 17 dead	World Nuclear Association, “Tokaimura Criticality Accident”, 2007

V Appendix E Chemical attack inside building – Sarin dispersal through ventilation system

This Appendix presents an example scenario and use of the template. The second and third order challenges are not included. These challenges have to be added subsequent to a consequence assessment and input from emergency personnel and stakeholders.

Scenario C1
Chemical attack inside building – Sarin dispersal through ventilation system
Scenario justification
Historical cases of intentional use of toxic chemicals to cause mass casualties are fortunately very few, the sarin attack in Tokyo in 1995 by the doomsday cult Aum Shinrikyo being the most infamous (Tu, 2002). The cult members dispersed sarin in several Tokyo subway trains. A similar type of scenario is used by the U.S. authorities as one of the national planning scenarios (The Homeland Security Council, 2004). This scenario is based on the above historical event and the U.S. planning scenario. It is an example of indoor dispersion of the highly toxic nerve agent sarin in a large building. Sarin constitutes a representative example of a highly toxic, odour- and colourless, volatile nerve agent, causing rapid onset of symptoms even upon exposure to low concentrations, and thus serves as a challenging case for emergency personnel. Anticipated key emergency response challenges are: (i) the time factor due to rapid onset of symptoms, (ii) the large number of casualties and (iii) the possibly contaminated hazard scene. This scenario will be used to identify critical event parameters, key operational functions for emergency personnel, to develop the PRACTICE toolbox and identify crucial emergency response gaps, possibly be used as a scenario in one of the validation exercises and included in the training kits. Other related scenarios from previous EU-projects are: • IMPACT WP100, scenario C4: nerve gas in a metro car • MASH WP 4, scenario 4: Dispersion of unknown toxic liquid in enclosed area • Toolkit WP6: Scenario 1 Dispersion of toxic liquid in enclosed area
Scenario outline
The highly toxic nerve agent, sarin, is dispersed inside the ventilation system of a conference hall during an event attended by 1200 persons. Individuals carry out the attack by breaking into the main ventilation facility. A bottle of sarin is emptied in the ventilation shaft downstream of the heat exchanger. The sarin evaporates, mixes with air and is transported into the hall through ventilation inlets situated close to the ceiling. Mild intoxication effects occur within minutes, while serious injuries and fatalities occur approximately 20 min after the release. In recent months several incidents have raised the political temperature in the region. The intelligence services have raised the threat level and increased their international cooperation, but no specific threat against the convention centre has been posed.

Cause	
Intentional (Yes/No/Both)	Yes
Profile of actor (if intentional)	The actors willing and capable to perform this type of attack are not a research topic in PRACTICE. The project draws on available analyses of historical incidents, in this case the chemical terrorist attacks in Japan. The religious doomsday sect Aum Shinrikyo which performed the sarin attacks in Matsumoto (1994) and Tokyo (1995) was established by Shoko Asahara in 1984. At the time of the attacks, the active core members consisted of about 1 400 persons who donated all property to the cult and lived on the cult's premises. The cult had substantial economic resources and many followers with technical-scientific background, thus the resources, competence and ambition to produce chemical and biological threat compounds. The cult used highly toxic substances such as the nerve agent VX to assassinate persons who left the cult. The cult experimented with both biological and chemical agents. From early 1990 the cult started experimental production of both C and B agents. The use of the biological agents botulinum toxin and anthrax bacteria did not succeed. The cult built a sophisticated facility for mass production of sarin in tonn quantities and had purchased huge amounts of precursor chemicals. The facility never started full production due to police investigations. Prior to the 1995 attacks the cult quickly produced sarin, which fortunately was unpure.
Description of cause	The possible motive for perpetrators to conduct a chemical attack like this is not known. The PRACTICE project can only draw upon the analyses of the incidents in Japan. The Aum Shinrikyo cult's direct motive for the 1995 attack was to stop police investigations against the cult's activities by attacking the subway station closest to the Tokyo Metropolitan Police headquarters.
Competence and resources	Competence and equipment for chemical synthesis is needed. This includes chemical precursors, laboratory equipment and facilities, and personal protective equipment.
Threat compounds and their properties	
Threat compounds	Sarin, GB, isopropyl methylphosphonofluoridate
Properties	Clear, colourless and tasteless liquid with no odour in pure form. Boiling point 147 ºC. The toxicity estimates (70 kg human) are:

Toxicity	Route and form of exposure	Exposure time (min)	Estimated value (mg min m^{-3})	Minute volume (l min^{-1})
ECt_{50} [a]	Inhalation and ocular, vapour	2 - 10	2	-
LCt_{50} [b]	Inhalation, vapour	2	36	15
LCt_{50} [b]	Inhalation, vapour	10	57	15
LCt_{50} [b]	Inhalation, vapour	30	79	15

[a] The inhalation dose that for exposure time, t, causes mild effects (miosis or rhinorrhea) in 50 % of the exposed population.
[b] The inhalation dose that for exposure time, t, produces lethal effects in 50 % of the exposed population.

Medical symptoms	Symptoms of intoxication are impaired vision (pin-point pupils, *i.e.* miosis), dizziness, headache, vomiting, runny eyes and nose, bloody secretion from mouth, diarrhea, fasciculation, convulsions, then respiratory arrest and death. Rapid onset of symptoms within seconds and minutes.
Availability	Not commercially available. Must be synthesised. Precursor chemicals are subject to export control measures under the Chemical Weapons Convention (CWC) and the Australia Group lists. However, these mechanisms can be circumvented. Production is not straightforward, but possible.
Dissemination	
Amount	The total amount dispersed is 0.42 kg
Release mechanism	Liquid spill in the ventilation shaft, subsequent evaporation and dispersal through the ventilation inlets.
Equipment	No special equipment needed for dissemination.
Physical state	Liquid which evaporates.
Fate	Sarin vapour will be transported through the ventilation system of the building.
Location	
Location description	Large convention hall. Permanently open access doors to other parts of the centre.

Weather	Cold winter/autumn conditions. Inlet air in the ventilation system is heated (16 ºC). The indoor temperature is 20 ºC.
Population at risk	1200 persons are inside the building. The attack occurs at a tourism trade fair. The population is a mixture of mostly healthy adults in all ages and some children. A CBRN incident has never happened before in this country, and the population at risk is totally unprepared. The population can be expected to obey police and other authorities' orders in crisis situations.
Time	Daytime, during the convention.
Other	
Indication or alert	
Announcement	No announcement is given by the perpetrators. The intelligence services have no specific information about the attack, thus no pre-warning is given.
Observations	The attack is not observed or heard.
Detection	If no detectors are in place, the indications of the attack will be observed symptoms. Exposed persons will quickly show symptoms.
Alert	Attendees will show signs of exposure to sarin, which can be mistaken for a heart attack. First responders will be called. The local security staff will initiate the fire alarm in order to open doors and evacuate the building.
Local safety and security measures	Camera surveillance, evacuation procedures, central fire alarm and associated procedures.
Possible consequences and development	
Reference time	Time zero is defined as the time when the medical dispatch centre receives the first call.
Minutes	Sarin will spread inside the building through the ventilation inlets. Casualties and fatalities will occur. People will start to evacuate the building. Fire alarm is triggered. First responders will arrive at the scene. The first responders will quickly realize that the incident is an attack.
Hours	Sarin vapour will be purged from the building. First responders will complete their tasks.

Days	The investigation will confirm sarin as causative agent. Building will be physically restored.
Months	Some casualties will experience long term medical effects and need long-term medical care. Post-traumatic stress disorder for many of the affected persons. Other psychological effects in the general population.

Impacts of the scenario:
The 3-tier impact model from the ASSRBCVUL project is used.

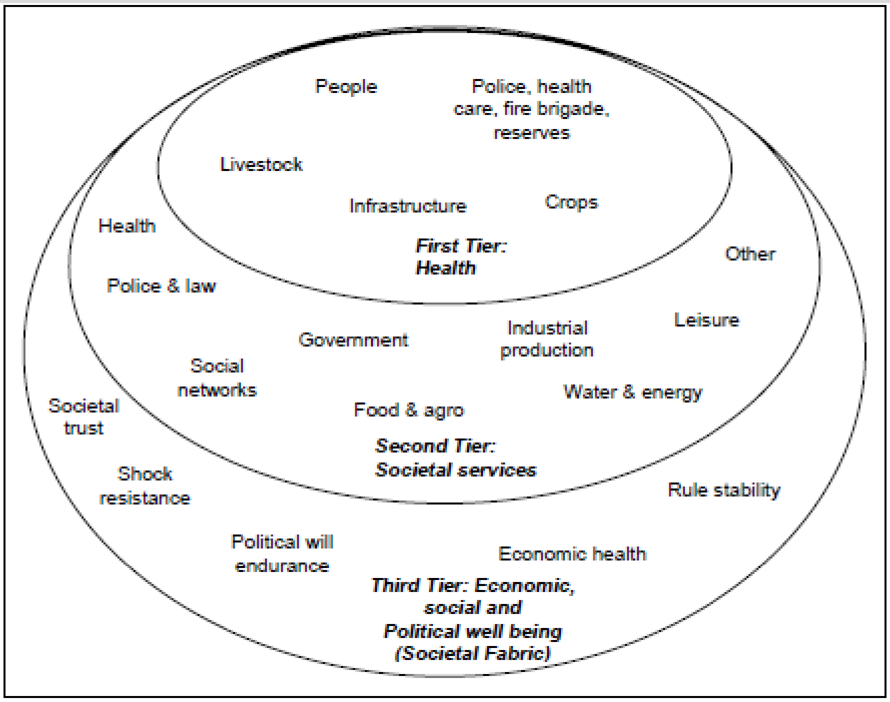


Figure 2.1. Model of impact areas in European society

ASSRBCVUL – Assessment of the vulnerabilities of modern societies to terrorist acts employing radiological, biological or chemical agents with the view to assist in developing preventive and suppressive crisis management strategies.

1st order challenges
Challenges related to the direct effects of the incident, i.e. effects on the population, first responders, authorities, infrastructure and the environment that are directly caused by the attack, accident, or disease.

Directly affected population	About 25-50% (300-600) casualties within 10-15 minutes. No casualties external to the building. Incapacitated people may remain in the building and die consecutively. Possibly mass panic in the course of evacuation of the building. Possibly secondary casualties from stampede effects.

First responders Are there plans, methods, equipment, procedures and training available?	Technical measures • Individual protective equipment (IPE) • Detection equipment • Sampling equipment and procedures • Laboratories for identification • Decontamination (if needed) • Establishment of safety zone • Forensic work Casualty care • Extract the victims from the hot zone • Registration • Decontamination • Triage and first aid • Transport of casualties to hospitals Organisation • Chain of command • Clear division of responsibilities Communication • Emergency services communication • Crisis information • Media communication
Health services	Preparedness to deal with casualties or fatalities among the first responders. Availability of drugs and medical treatment capacity. Plans for alternative locations and handling of worried well.
Command and control centre	Coordinating response. Methods and procedures for keeping abreast with the development.
Site/building/infrastructure stakeholder(s)	Evacuation plans. Building restoration capacities.
Other authorities	Police investigation and forensic work. Inter-agency communication and cooperation. Correct and verified information to the public and the media. Establishment of crisis centers for relatives and the public.
Media	Plans for cooperation.
Infrastructure	Possible physical effects. Establish the possible need for decontamination. Availability of methods for verification of contamination and safe levels by sampling and identification before restoration of the

	building.
Environment	Assessment of the risk and duration of contamination.
Authorities in other countries	Plans for cooperation with other countries. Availability of equipment and medical treatment.
International organisations	Knowledge of possible support. The Organisation for the Prohibition of Chemical Weapons (OPCW) in the Hague has a capacity to provide expert advice, send experts and analyse samples at designated laboratories.
2nd order challenges *Challenges that indirectly cause problems or disruption for the population, the authorities and infrastructure.*	
Population	
Government	
Health services	
Police and law	
Food and water production and distribution	
Communication	
Transportation	
Energy supply	
Industry and commerce	
Leisure	
Other	
3rd order challenges *Overarching societal, political and economic effects and challenges indirectly caused by the incident.*	
References	
Relevant literature	A. A. Tu, Chemical Terrorism: Horrors in Tokyo Subway and Matsumoto City, Alaken, Inc., Fort Collins, CO, 2002. Planning Scenarios, Executive Summaries, The Homeland Security Council, July 2004, http://www.globalsecurity.org/security/library/report/2004/hscplanning-scenarios-jul04 exec-sum.pdf (accessed 6 August 2008).

	M. Endregard, B. A. P. Reif, T. Vik, O. Busmundrud, Consequence assessment of indoor dispersion of sarin—A hypothetical scenario, *Journal of Hazardous Materials* 176 (2010) 381–388.