Major Incidents: Examples and Experiences

2

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2.1 Terminology

Traditionally, major incidents and disasters have been classified as (1) those caused by human beings or by the development caused by human beings, referred to as "*man-made disasters*," and (2) those caused by changes in nature or climate, referred to as "*natural disasters*." To the first category have belonged incidents that occur as a consequence of technical failures within, for example, industry or transportation; to the latter category belong events such as earthquakes, volcanoes, hurricanes, and floods.

Such classification is not totally relevant because many of the so-called "natural disasters" are consequences of human activities. During recent years the theory that climate changes caused by man indirectly have increased the risk for certain types of natural disasters, like hurricanes and floods, has gained support. The "starvation disasters" witnessed today are to a significant degree the effect of an inaccurate distribution of resources between poor and rich countries, overutilization of nature, and political actions. On the other hand, incidents classified as "man-made" may have been caused by climatologic changes, for example, airplane and ship accidents caused by heavy winds.

A more relevant classification may be the following:

- Incidents that occur as a consequence of technical development
- Incidents intentionally caused by man
- Incidents that occur as a consequence of changes in climate and nature

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2.2 Incidents That Occur as a Consequence of Technical Development

Human beings have always promoted technical development, but development has never gone so fast or been so extensive as it has during recent decades. Thanks to advanced techniques, we have gained a successively increasing standard of living, but through this way of living we consume resources with little attention paid to how this influences nature, climate, and the needs of coming generations. The demands of a continuously increasing standard of living has generated dramatically accelerating industrial production and increased traveling, with faster and bigger transport facilities. Because economic interests often are stronger than concerns about security, the risk for accidents with many people involved, both directly through technical development and indirectly by the influence on nature and climate, is increased.

Incidents that occur as a consequence of this development are those caused by:

- transport– in the air, at sea, on rails, and on roads;
- hazardous material – production, transport, and use of flammable, explosive, chemical, and toxic substances or substances causing irradiation;
- fires in buildings, industries, and transport systems;
- public and political events – gathering many people together in limited areas; for example, sporting events, festivals, political meetings, or demonstrations;
- the collapse of buildings or construction projects where economical interests have been given priority before security; and

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- disturbances in technical systems, such as computer and telecommunication systems, on which we are increasingly dependent in all functions of the community and that are vulnerable to disturbances and overload during critical situations.

Incidents in these categories can be caused by *mistakes in construction and management*, the so-called "human factor" that never can be eliminated completely by security systems. They can also be caused by *underestimation of or disregarding risks*; for example, as a consequence of economic interests or competition. The Estonia ferry disaster in the Baltic in 2004 (described below), where 852 people died, is a tragic example that we are exposed to risks that are well known but neglected. No responsible professional could be unaware of the risks connected with ferries constructed like the one lost, or that safer constructions are possible but with somewhat reduced capacity related to size. This is may be an example that shows we have to pay a price for our way of living; however, that price should include increased efforts in preparedness to handle incidents like this. However, this is not always the case: After the Estonia disaster, in which the majority of the survivors (97 of 137 people) where saved by helicopters, access to helicopters has not been increased but reduced. Military helicopters are now less available in an attempt to save money and have not been replaced by any alternative. There are, unfortunately, many similar examples.

2.2.1 Transports

Never before in history have so many people and so much material been transported between different parts of the world. Incidents consequent to this are:

- airplane accidents;
- ship accidents;
- accidents on rail; and
- accidents on road.

2.2.1.1 Airplane Accidents

The intensity of air traffic is continuously increasing. For example, the number of air passengers in the United States was estimated to exceed 985 million in 2009 compared with 580 million in 1995 – almost double over 15 years. Through each of the big airports in Europe pass between 50 and 100 million passengers every year.

The number of accidents during the last years has been low in relation to the intensity of traffic. According to the latest available statistics from the US Aviation National Transportation Safety Board, the frequency of incidents was 0.223 of a total of 11,200,000 takeoffs; of those, 0.018 had a fatal outcome. This means that the risk of being exposed to an incident is 1 in every 500,000 takeoffs, with a fatal outcome of 1 in every 5,500,000 takeoffs, which statistically makes traveling by air by far the safest method of transport.

Even if incidents are rare, they do occur. Increased competition between airlines has led to increasing demands on efficiency, which can be a threat to security and is now focus of debate. The continuously increasing traffic density around major airports also involves a risk. Of all incidents, 15% occur in connection to takeoff, 55% in connection to landing, and the rest during flight.

In accidents occurring close to airports, effective and fast rescue actions in combination with construction of safer airplanes have increased the number of surviving casualties, a significant trend during recent years. One such example is the 1989 airplane crash in East Midlands, United Kingdom, when a Boeing 737 did an emergency landing close to the airport because of engine failure. The airplane was heavily destroyed (Fig. 2.1), but because of rapid and effective fire secure and rescue, 87 of the 118 passengers survived initially, but 16 died later. Many had severe injuries, and the load on the medical care was heavy. The experiences have been carefully reported in a separate publication (Wallace et al. 1994).

Incidents can also occur in areas far from available roads, which means difficult problems for rescue and primary medical care. One of the most tragic examples of this is the jumbo jet crash in Japan in 1985, which was caused by a construction error in the airplane and lead to the death of more than 500 people. The rescue and medical staff did not reach the aircraft until after 14 h, and a few survivors witnessed that many more had survived the crash but died waiting for help. There are other examples of similar delays, emphasizing the importance of faster localization and faster transport of medical staff to the scene during such situations.

Fig. 2.1 The 1989 airplane crash in East Midlands, United Kingdom. A Boeing 737 crashed during an emergency landing close to the airport because of engine failure. Despite extensive destruction of the aircraft, 87 of the 118 passengers initially survived the crash. Sixteen of these died after primary treatment. The photograph illustrates a clear trend in airplane crashes: Because of faster and more effective actions during rescue and fire control, as well as improved airplane construction, the chances of surviving an air crash have increased, but this also increases the load on health care with many severely injured survivors (Photo Scanpix, with permission)

One type of incident that has increased in frequency during recent years is airplane crashes in buildings or crowded areas. Surprisingly often, flights to big airports pass over densely populated areas. One example is the an airplane crash in Amsterdam in 1991 (Arturson et al. 1994), where a jumbo jet flew straight into a high building (Fig. 2.2a, b). Miraculously only 50 people were killed; this was a transport flight with only crew on board, and many people living in the houses were outdoors on that occasion. However, it is easy to imagine what the outcome could have been if the airplane had been full of passengers and everyone was at home inside the houses (Arturson et al. 1994).

Another example of crashes in densely populated areas is the air show in Ramstein, Germany, in 1988, where an airplane, after a collision, crashed in the middle of the crowd of spectators, resulting in 43 dead and more than 400 injured (Brismar and Lorin 1990). In Sweden in 1993, during an air show over the center of Stockholm, a new military airplane crashed only 100 m from a long bridge crowded with spectators, which easily could have generated a similar scenario.

To this kind of scenario we today have to add airplane crashes caused intentionally in densely populated areas (see below in the section "Terrorist Actions").

Increased traffic intensity also has led to an increased risk for *accidents on the ground*. The most severe incident of this kind to date was the collision between a Dutch and an American aircraft at the airport of Tenerife in March of 1977; 581 were killed and more than 60 were severely injured. In October 2001, at the Linate air port in Italy, a collision occurred on the ground between a Scandinavian passenger aircraft and a private aircraft, which was caused by a mistake made by the airport flight control and resulted in the death of 118 passengers. The psychological management of relatives of victims killed in a foreign country, a common situation in air crashes, was evaluated after this accident in a special report (Berg-Johannesen et al. 2006).

The scenario of injuries in airplane crashes is dominated by blunt trauma and has a pattern of injury similar to that seen in road traffic accidents. The majority (60–65%) have multiple injuries. Burns have been registered in 8% of injured survivors, where the dominant cause of

Fig. 2.2 The 1991 airplane crash in Amsterdam. A jumbo jet coming in for a landing crashed straight into a high-rise apartment building, causing severe destruction and fire. Because this was a transport flight with only crew on board, and because very few of those living in the houses were there at the moment of the crash, the number of casualties was limited, but could have been much higher if the aircraft had been full of passengers and everyone at home in the buildings. (**a**) Almost 70 tons of fuel caused a violent fire. (**b**) The site of the crash in the middle of a living area. Today, many flights pass today over crowded cities or other densely populated areas on the way to airports, involving a risk of incidents during which the outcome of dead and injured can be extremely high (Photo Scanpix, with permission)

death has been inhalation of smoke. One such example is the airplane crash in Manchester, United Kingdom, in 1985, where a passenger aircraft caught fire during take-off and resulted in 55 dead, of whom 80% had cyanide levels in the blood that exceeded the level that causes unconsciousness (O'Hickey et al. 1987; Fries 1991).

A specific injury pattern is seen in *helicopter crashes*, in which fires are rarely reported because of safer fuel systems. Blunt trauma dominates, with a high in incidence (>60%) of head injuries, and many vertebral injuries are caused by the deceleration trauma (Bledsoe and Smith 2004).

Airplane Crashes: Summary of Experiences

- Even if airplane crashes are rare in relation to the intensity of traffic, the continuously increasing traffic and demands for efficiency involve potentially increasing risks.
- Because of more rapid and effective rescue actions at airports, the number of injured survivors after airplane crashes has increased, thereby increasing the need for and importance of immediate and accurate medical response.
- Airplane crashes during flight are rare but can put high demands on rescue service and medical care if they occur far from available roads.
- Crashes into buildings or in densely populated areas may result in extensive casualties.
- Crashes caused intentionally is a new scenario that must be included in calculated risks.

2.2.1.2 Ship Accidents

The development of sea travel includes bigger ships with increasing numbers of passengers, higher speeds, and higher demands on keeping to schedules regardless of weather conditions. Between Sweden and its surrounding coasts, 39 million people are transported every year – four times the population of the country – indicating the frequency of travel by sea. Many ferries can today take more than 2,500 passengers with simultaneous transports of cars and trucks with any kind of material.

The loss of the passenger ferry Estonia in the Baltic Sea in September 1994, which resulted in the deaths of 852 people (Brandsjö et al. 1997), is one of the bigger disasters at sea during recent years and is of interest because it was not an overloaded ship run without attention to security, but a modern, high-technology ferry cruising in an area with a normally high standard of security. For many, this was a wake-up call from believing that "such things cannot happen." Still, this was not the first ferry accident of this kind (Table 2.1). Ferries of this kind have a big open cavity inside, which is separated from the water outside by rather thin walls and by a big front door wide enough for trucks and trains to pass through. If water comes into this cavity, a level up to 10–15 in. is enough to make the ferry roll around; if the water (by the movement of the sea) collects on one side, there is nothing between to stop it. This process can happen fast, so there may not be enough time to evacuate passengers or to launch lifeboats; this was exactly what happened to the Estonia after a leak through the big frontal doors, the cause of which is still unknown but probably it was caused by a combination of high speed and heavy waves. This was not the first time this happened: In 1987, the ferry "Herald of Free Enterprise" rolled around just after departure from the harbor in Zeebrügge, Belgium, this time because someone had forgotten to close the front doors. More than 200 passengers died, and the outcome would have been even worse if it had not occurred in shallow water with parts of the ferry still above the surface (Lorin and Norberg 1998). Similar accidents have been described before that of the Estonia (Table 2.2).

Table 2.1 Major incidents with ferries during the last 20 years

Year	Ship	Position	Cause	Number of dead
1987	Donna Paz	Philippines	Collision, fire	2,000
1988	Herald of Free Enterprise	Belgium	Technical failure	188
1990	Scandinavian Star	Sweden	Fire	158
1991	Salem Express	Red Sea	Ground strike	480
1993	Jan Hewelius	Baltic Sea	Storm	55
1993	Ferry	South Korea	Storm	292
1994	Estonia	Sweden/ Estonia	Technical failure	859

Table 2.2 Examples of major incidents in sport arenas during the last 15 years

Year	Place	Cause	Dead	Injured
1985	Bradford, UK	Fire	55	200
1985	Brussels, Belgium	Congestion	39	437
1988	Katmandu, Nepal	Congestion	80	700
1989	Hillsborough, UK	Congestion	96	400
1991	Orkney, South Africa	Congestion	40	50
1991	New York, USA	Congestion	8	28
1996	Guatemala City, Republic of Guatemala	Congestion	84	147
2001	Johannesburg, South Africa	Collapse	43	250
2001	Ghana, India	Congestion	123	Unknown
2010	Phom Phen, Cambodia	Collapse	349	Unknown

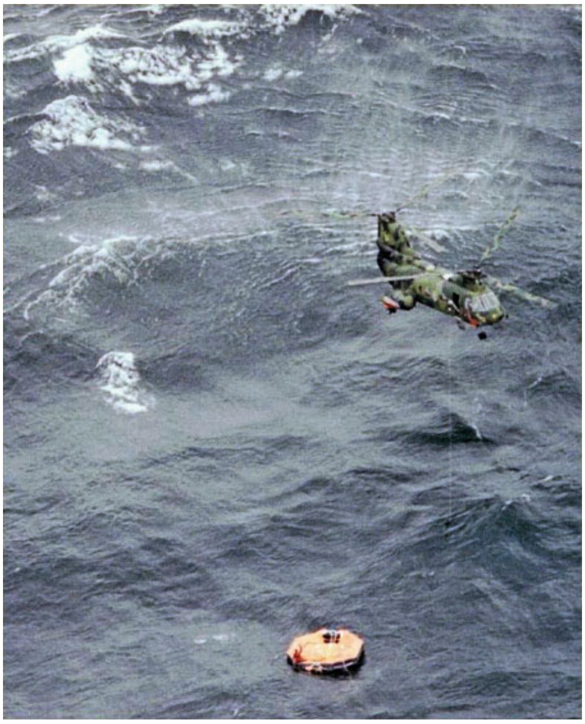

Fig. 2.3 Ninety-seven of the 137 survivors of the Estonia ferry disaster were saved by helicopters with surface rescuers that could pick up survivors from the water. This work was demanding and risky in heavy wind and waves. The rescuers had no chance to pick up all passengers, but gave priority to those showing signs of life. This included a risk of leaving hypothermic victims with a possibility of survival on the rafts, but it was probably the best possible triage under these difficult circumstances (Photo Scanpix, with permission)

Of the 989 registered passengers and crew on board the Estonia, 852 drowned, probably because most of them never had time to get out. Of the 137 survivors, only 40 could be picked up by other ships that were available quickly but were not prepared to pick up people from the water in heavy waves. Ninety-seven survivors were picked up by helicopters from Finland and Sweden (Fig. 2.3). The helicopters arrived late: the first, 2 h after the incident, and the majority arrived after several hours. In water this cold – 10°C (50°F) – the chance of surviving more than 3 h is less than 50% and falls rapidly as time spent in the water increases. In other words, rapid access to helicopters is vital. Still, no steps have been taken to increase access to helicopters; on the contrary, access has been reduced significantly by the removal of military helicopters on the Swedish side. The ferries themselves look the same, and although some strengthening of the front gates has occurred, other reasons for leakage remain in these crowded ferries, which run with high speed in heavy traffic and bad weather conditions. Examples of learning and disregarding the lessons learned is not unusual in this field.

Accidents at sea have moved toward an increasing number of dead with every incident, probably because the ships have become bigger and the number of passengers higher. Of 353 registered accidents between 1970 and 1985, 50,000 people died, whereas the 20 biggest accidents during 1980–1995 caused only 15,400 deaths. The largest accident at sea during peace time so far is the collision between a Philippine passenger ferry and an oil tanker in 1987, which resulted in the loss of more than 2,000 lives.

Fire on board ships is another cause of death at sea. The fire on board the passenger ship Scandinavian Star off of the Swedish coast in 1990 caused the deaths of 159 people. This incident describes the importance of collaboration between countries and organizations in these complex rescue actions (Almersjö et al. 1993).

Ship Accidents: Summary of Experiences

- Bigger ships, higher numbers of passengers, higher speeds, and competition along with demands to keep time tables independent of weather conditions have increased the number of incidents, with many dead.
- The construction of big ferries, where economical interests are given priority before safety, accelerates this risk.
- Rescue actions at sea put big demands on collaboration between countries and organizations and require training for good preparedness.
- Rapid access to helicopters can be of vital importance for survival in heavy weather and/or low water temperatures and must be included in planning and preparedness.
- Hypothermia and drowning are conditions outside normal routines for most medical staff, and both require increased knowledge and training.

2.2.1.3 Accidents on Rail

The total number of dead in train crashes may seem limited compared with those dead in road traffic incidents, but when train accidents occur, the number of simultaneously injured can be high, putting demands on preparedness and response.

Fig. 2.4 (**a**, **b**) The high-speed train incident in Eschede, Germany, in June 1998. An overheated wheel locked and cut the rail off, and the wagons behind it derailed and crashed into a concrete bridge, which collapsed and crushed parts of the train. One hundred one people died and 87 were severely injured. The pictures illustrate the difficult and time-consuming work to rescue many trapped patients (From Hülse and Oestern 1999 with permission)

The speed of trains has increased greatly during the last decades. How much this influences the risk for incidents remains unknown. In Japan, one of the leading countries in fast train travel, more than 10,000 persons have been injured in more than 80 registered train crashes during the last 2 decades. A well-documented example of an accident with a high-speed train was the derailment in Eschede, Germany, in June 1998 (Hülse and Oestern 1999). The cause was overheating in a wheel, which caused it to "lock" and thereby cut off the rail, which led to the subsequent wagons in the train being derailed. This was just before the train was to pass under a concrete bridge. Instead, the derailed wagons crashed into the bridge (Fig. 2.4) which collapsed and caused extensive damage. One hundred one people died and 87 were severely injured, and many were trapped, which required an extensive rescue action. The value of helicopters for transport and bringing resources to the scene was clearly demonstrated during this incident. Overheating in wheels, resulting in damage to the rail and derailment, is a well-known phenomenon that has been reported both before and after the Eschede derailment but with less severe consequences.

The biggest incident on rail with regard to the number of dead and injured happened in Bashkira, Ukraine, in 1989. Leaking gas from a gas line caught fire in the same moment as two trains, on their way to and from a tourist resort, met, which probably induced the fire. Eight hundred people, of whom many were children, were treated for burns, and a large number of people died (calculations say more than 2,000, a figure that never was confirmed). Rescue and medical teams from many countries participated in the rescue operations (Kulaypin et al. 1990; Becker et al. 1990).

Incidents on rail also include trams and underground trains in major cities. In Gothenburg, Sweden, in March 1992, a tram without a driver ran downhill in the center of the city after the breaks failed when it was parked on top of the hill. With increasing speed, the train crushed everything in its way, resulting in 42 injured and 13 dead (Almersjö and Kulling 1994).

Special problems are connected to incidents occurring in tunnels: trapped passengers and difficulties with gaining access to and evacuating casualties. The collision of two trains in the London subway in 1964 that left 30 dead and 150 injured, and a fire in King's Cross subway station (also in London) in 1987 that left 31 dead and 60 injured (Hallén and Kulling 1990), are examples on this. In the terror attacks in London in July 2005 (further described below), three of the simultaneous attacks were directed at the London subway (Aylwin 2006). The Sarin gas attack in Tokyo in 1995 (Kyriacou 2006), also described below, is another example of a terror attack directed at an underground railway.

Accidents on Rails: Summary of Experiences

- Increasing speed on our railroads has increased the risk of incidents with many injured.
- Special problems during rescue actions include trapped patients and difficulty gaining access to and evacuating the injured, resulting in time-consuming operations with demands on treatment on-site and during extrication.
- These problems increase further when incidents occur in underground railways or tunnels, which also have been targets of terrorist attacks during recent years.

2.2.1.4 Accidents on Roads

Serial collisions on highways during darkness, fog, or in slippery conditions can result in many injured and dead, and several such incidents have been described during recent years, a consequence of increasing traffic intensity in urban areas. Trapped patients and traffic jams reducing access to the scene are problems described in connection to such incidents. An important lesson is that road traffic accidents under special circumstances can justify major incident response.

A more common cause of major incidents in road traffic is *bus crashes*. The size and speed of buses have increased, and the use of buses in the tourist industry has also increased. In Sweden, where buses are frequently used in charter traffic, 15 major incidents with buses have been reported during the last 2 decades, with more than 500 injured and 50 dead. This has resulted in efforts to increase security by better construction and seatbelts as standard. Figure 2.5 shows one of the latest incidents, a collision between two buses on a slippery road in the north of Sweden, far from the nearest hospital, with six dead and 62 injured, many of them severely. Another reminder that bus crashes can lead to a heavy load on local hospitals in rural areas.

Road Traffic Accidents: Summary of Experiences

- Serial collisions on highways during high traffic intensity and bad weather conditions can cause major incidents. Care of trapped patients before they reach a hospital may be needed during time-consuming extrications.
- Bus crashes with many injured and dead have increased with increasing use of high-speed tourist buses and are another cause of major incidents on roads; the resultant load on medical care in rural areas can be considerable.

2.2.2 Accidents Caused by Hazardous Material

Next to terror actions, accidents caused by hazardous material have increased most during recent years. The risks are apparent: In Sweden (nine million inhabitants),

Fig. 2.5 The bus crash in Rasbo close to Uppsala, Sweden, in February 2007 resulted in six dead and 62 injured, many severely. The picture illustrates the difficult and time-consuming rescue operation of many trapped patients (Photo Scanpix, with permission)

every year 18 million tons of flammable, explosive, chemical, and toxic substances are transported on our roads, and an additional 3 million tons are transported on rails, often passing through densely populated areas.

The most serious incident with *flammable and explosive substances* to date is the propane explosion in San Juanico, Mexico, in 1984 (Arturson 1987). A series of explosions after a leakage in a propane depot in a densely populated area close to Mexico City resulted in more than 7,000 burn-injured casualties; 600 of them died. The use of propane is increasing, and the San Juanico disaster is only one of many incidents of this kind. If stored propane is leaking (for example, because of deficiency of a valve or collision) and starts to burn, the storage tank is heated and the liquefied propane starts to boil and becomes vaporized to gas under pressure, which finally ruptures the tank. This leaking gas is highly flammable and can cause an explosive fireball several hundred meters in diameter, burning everything in its way. This phenomenon is called *BLEVE* (boiling liquid vapor explosion). The relatively low mortality among those who were severely burned in San Juanico was probably because of the extensive resources for treating burn injuries in Mexico City. In several places in Europe the same incident would have demanded international collaboration to care for all the burns.

The large number of injured in San Juanico was partially caused by the fact that homes had been built quite close to the propane depot. A *BLEVE* disaster more representative of European conditions was the propane explosion in Los Alfaques, Spain, in 1978. A truck with propane containers refilled the supplies in a camping area close to a popular swimming resort. The truck ran into a stone wall; there was a leakage and fire resulting in a *BLEVE* that caused more than 100 immediate deaths and 140 burn injuries, many of which were severe. The triage and primary management of the injured, following different treatment lines with different strategies, has been carefully analyzed and significantly contributed to the knowledge in this field (Arturson 1981).

Several other BLEVE disasters have occurred both before and after San Juanico, and the risk of other remains considering the frequent, extensive, and increasing transportation of propane.

Accidents with *leaking gas* may demand evacuation of large numbers of people from the risk zone. An example of this was the train crash in Missisauga outside Toronto, Ontario, Canada, in 1979. The train was carrying a variety of hazardous material, among them propane and chlorine gas. The propane exploded in the crash, causing damage to the chlorine gas wagon, where leakage occurred. More than 210,000 people had to be evacuated from the disaster zone. However, injuries were limited thanks to well-performed rescue and evacuation processes (Baxter 1990).

To date, the worst disaster caused by *toxic substances* happened in Bhopal, India, in 1984. Through a failure in a safety valve, leakage occurred and released 43 tons of methyl isocyanate, an intermediate product in the production of pesticides. Five hundred twenty thousand (520,000) people were exposed; of those, 8,000 died during the first week, and another 8,000 died later. Ten thousand were treated for symptoms caused by the exposure, and they may still have symptoms or impairment as a consequence of the disaster. The disaster has been carefully retrospectively analyzed and the long-term effects followed up (Eckerman 2005).

The terror attack with the nerve gas Sarin in Tokyo's underground railway in 1995 (already mentioned and described in detail below) is another example illustrating the large number of injured and dead that can be a consequence of incidents of this kind. The management of incidents that include hazardous material is dealt with in detail in a separate chapter of this book.

Accidents Caused by Hazardous Material: Summary of Experiences

- Incidents caused by hazardous material can result in numbers of dead and injured widely exceeding those caused by mechanical violence.
- The risk of such incidents is increasing parallel to increased production, transport, and use of such substances.
- Preparedness must include plans for decontamination and evacuation of large numbers of people.
- Staff within risk zones should not work without personal protection equipment, which must be clearly defined, and special staff must be trained to use such equipment.
- Antidotes for substances used in or transported through an area must be stored and rapidly available in that area.

2.2.3 Accidents Caused by Radiation

Nuclear plants are needed for the supply of enough energy to permit our present standard of living. Even if safety protocols are rigorous and the technology advanced, they are operated by human beings, and human beings can and do make mistakes. Nuclear plants also may be potential targets for terrorism, and they are vulnerable to natural disasters that we cannot control. This means risks, and if incidents occur, the consequences can be severe and extensive.

Incidents so far have been few and mainly caused by technical failures. One example is the Chernobyl disaster in Ukraine in April 1986 (Brandsjö et al. 1992). The reactor exploded after security systems had been disconnected for a test. In a subsequent violent fire, a large part of the radioactive content of the reactor was released and spread over a wide area. The number of immediate deaths was limited to 31 (reactor and rescue staff). More than 100 were treated for irradiation injuries. The long-term consequences for the contaminated areas have been difficult to determine. A change in the pattern of malignant tumors, especially among children, has been registered in areas close to the disaster. One lesson to be learned, in addition to matters of reactor safety, was the need for better preparedness to determine contamination and inform about risks.

Just when the manuscript for this book was delivered to the publisher, Japan was hit by the one of worst earthquakes ever registered (9.1 on the Richter scale). It occurred off the coast of Sendai and created a tsunami wave that hit the coastline with devastating effects (Fig. 2.10). Several of the Japanese nuclear plants are located along this coastline and were hit by the wave. Reserve electricity and cooling systems were destroyed, leading to overheating of the plants with a risk of meltdown and severe leakage of radiation (Fig. 2.11). At the time of this writing, the consequences of this are difficult to overview, and information available at the time of printing will be summarized in Chap.11 on irradiation incidents.

Our standard of living requires more energy than we can produce with conventional techniques without destruction of nature, and of alternative sources of energy, nuclear power has been considered the only one available today that has sufficient capacity to fill our needs. To believe that we can master this advanced technology with total elimination of risks is, of course, not realistic. What is happening in Japan right now is an example that to live the way we do requires acceptance of risks. This, however, also means a responsibility to inform people about these risks and take all steps we can take to prepare ourselves to handle them. On this point, our political leaders on all levels still have a long way to go.

Irradiation injuries are not restricted only to nuclear plants; they have occurred as long as radiation has been part of our technology. During the last few decades, more than 3,000 accidents with radiation have been reported to the International Atomic Energy Association, many of them severe and leading to death or severe diseases. Therefore, knowledge about triage, diagnosis, and primary treatment of such injuries should be included in disaster medicine education. This is dealt with in chap. 11.

Accidents Caused by Radiation: Summary of Experiences

- Nuclear power will, for the near future, be necessary to maintain our present standard of living, and, even with rigorous security, risks for incidents can never be eliminated completely.
- Such incidents may lead to contamination of wide areas, and consequences are difficult to overview.
- This requires prepared systems for rapid determination of irradiation, information, decontamination, and evacuation, which have to be included in disaster preparedness and in education and training in disaster medicine.
- In addition to nuclear plants, substances causing irradiation are used in many areas of our community, and many incidents are reported every year, requiring the same kind of attention and preparedness as for other types of incidents.

2.2.4 Accidents Caused by Fire

The fire brigade in a country like Sweden (nine million inhabitants) is involved in 30,000–40,000 missions every year because of fire. Burn injuries are registered in 20,000 people every year, but only 10–15% of these need hospital care, of which only 1% (approximately 200 people) need treatment in a specialized burn unit.

Fires inside buildings or ships usually do not cause a high number of burn casualties because most of those injured by fire usually die from inhalation of toxic gases. For example, the fire in the ferry Scandinavian Star (described above) left 159 dead, but only 4% of those died from burn injuries. The rest died because of lack of oxygen in combination with inhalation of gases as carbon dioxide, carbon monoxide, and cyan hydrogen.

Fires outdoors, on the other hand, can cause extensive numbers of burns. One example is the propane explosion in San Juanico, Mexico (described above), which resulted in more than 7,000 burn casualties. Another example is the intentionally caused fire in the Bradford (UK) football stadium in 1985, which left 50 dead and several hundred survivors with burn injuries.

Fire in high buildings is a special and increasing problem for rescue services. An example of such an incident in a modern hotel is the fire in the MGM hotel in Las Vegas, Nevada (USA) in 1980, with 84 dead and more than 700 injured (Buerk et al. 1982). Another more recent example is the World Trade Center disaster in Ney York City in 2001, which is described in further detail below under "Terror Actions."

Public events seem to include an increased risk for large numbers of burns, often by intentionally caused fires. One of many examples is the discotheque fire in Gothenburg, Sweden, in November 1998, which resulted in 63 dead and 182 injured. One hundred fifty of the injured needed in-hospital care and 74 required intensive care because of severe burns and/or smoke inhalation (Cassuto and Tarnow 2003). Because the number of beds in specialized burn units is limited and usually not adapted to major incidents, these kinds of incidents require national and possibly international collaboration, with distribution of patients requiring special burn care over a wide area, even if the primary treatment and triage has to be done on site as much as possible with support from burn specialists. At the Gothenburg fire, all specialized burn units in Sweden were involved, and some patients needing special burn care had to be transferred to Norway.

Fires in industries may have severe consequences depending on the products produced. One example is the fire in a pyrotechnic industry that produced fireworks in Enschede, the Netherlands, in May 2000, which resulted in 20 dead and more than 200 injured (Fig. 2.6).

A chapter in this book is devoted to the special problems connected to management of large numbers of burns and describes principles of triage and primary treatment.

Accidents Caused by Fires: Summary of Experiences

- Fires may cause large numbers of burn casualties, many of which will require special resources for successful outcomes. Special burn care facilities in most countries are not adapted for mass-casualty situations, which require planning and preparedness for national and international collaboration for management of many injured, including transportation.

Fig. 2.6 Explosion in a pyrotechnical industry in the center of a densely populated area in Enschede, the Netherlands, in May 2000, resulting in 20 dead and more than 200 injured (Photo Scanpix, with permission)

- Primary management and triage has to be done at the primary receiving hospital because of the time factor, and, as an important part of preparedness, this requires knowledge about principles both for triage and primary treatment in all hospitals receiving trauma patients.
- The major cause of death in fires occurring indoors or inside transport units is smoke inhalation. Diagnosis and treatment of inhalation injuries is therefore an important part of this knowledge.

2.2.5 Accidents During Public Gatherings

Public gatherings such as sporting events, political meetings, concerts, and shows, involve a risk in themselves because many people are collected in limited areas, which can be difficult and time-consuming to evacuate. Examples of the effects of fire during such events have been described above. But such gatherings can turn into disasters without fire: Only 1 month after the fire in the Bradford football stadium in England, 40 people were killed and 400 were injured in a football stadium in Brussels after a confrontation between supporter groups, leading to the mass movement of spectators that crushed many to death and injured even more. There are many similar examples of mass-casualty situations caused by panicked movement in crowded sport arenas or stadiums (Table 2.2).

Mass gatherings of any kind are a potential target for terrorism because it is an easy way to cause the biggest possible numbers of dead and injured and at the same time attract attention and glamor for the terrorist group behind the attack.

Accidents Connected to Public Gatherings: Summary of Experiences

- Large gatherings of people, regardless of purpose, constitute a potential risk for mass-casualty situations that justifies attention and accurate preparedness within the medical care system.

- Panic movements alone, without additional causes of injury, are enough to kill and injure large numbers of people.
- Restrictions on the number of people needed to enforce rules, secure evacuation lines, barriers reducing the effect of panic movements, and sufficient numbers of security guards are safety measures that should not be limited by economic interests.

Collapse of Buildings: Summary of Experiences

- Collapse of old and new buildings and buildings under construction can occur without, or with only minimal, external violence, and this should be taken into consideration during disaster planning in urban areas.
- The scenario and pattern of injuries is similar to that caused by earthquakes. and experiences from such disasters should be considered in the planning.

2.2.6 Collapse of Buildings and Constructions

Experiences show that both old and new buildings can collapse without external violence, just because of failures in construction – perhaps a combination of human errors and/or lowering priority of safety because of economic interests. One example is the collapse of the Ronan Point Apartment Tower in London in 1968 (Lee and Davis 2006). This totally new building was 70 m high, with more than 100 fashionable apartments into which people just had moved. A small gas explosion on the top floor resulted in a domino effect causing total collapse of the whole building down to the bottom floor – similar to the collapse of the World Trade Center buildings but without external cause. Miraculously, the majority of the 260 people in the building managed to get out because the collapse proceeded slowly, but this and other incidents illustrate that even modern buildings can have fatal errors in the construction.

The scenarios in these incidents are similar to that during earthquakes: The least severely injured come out first; the more severely injured, who technically require extrication first, come out later, often with complex and severe injuries. Blunt trauma dominates the pattern of injuries.

Bridges can also collapse, with fatal consequences. An example is the collapse of the Sunshine Skyway Bridge in Tampa Bay, Florida, in 1980 (Melville and Rahman-Kahn 2006), which was caused by a tanker that because of reduced visibility ran into one of the pillars. The whole central part of the bridge that was full of traffic collapsed. Thirty-five people died and many were injured.

2.3 Disturbances in Technical Systems

This type of risk has been added recently to the bank of potential scenarios. Technical development has facilitated our lives in many ways, but it also has made us highly dependent on this technique working properly. Many people are most likely unaware of how vulnerable we will become if these systems fail. Many functions in our community – telecommunication, transport systems, industry – are totally based on such techniques and because they usually work under normal conditions, limited efforts to create reserve systems have occurred.

In the event of major incidents and disasters, there is a high risk that these systems will fail – either damaged by the cause of the incident, intentionally destroyed (as in terrorist actions), or just overloaded. One example is the breakdown of the central computer systems during the World Trade Center disaster in 2001 (Connocenti and Azima 2003). This clearly illustrates the need for reserve and backup systems as an important part of preparedness for major incidents. Unfortunately, this is one part of our planning where much remains to be done.

The health care system has, during the last few years, been dependent on computer techniques to an extent that not everyone is aware of or considers. Anyone that has experienced a collapse in the central computer system in a big hospital has had that frightening experience: practically every function in the hospital is paralyzed – results of laboratory tests cannot be provided, necessary supplies cannot be delivered, technical functions fail, and telecommunication fails. If this happens during a major incident, the consequences might be fatal if reserve and backup systems are not prepared as part of the disaster planning.

To these potential risks we must add the risk of intentional attacks on our computer systems. In the summer of 2007, the country of Estonia was exposed to a *cyber attack*, i.e., large numbers of e-mails were simultaneously sent to the central severs of the country, which led to a temporary but illustrative breakdown. The attack was interpreted as a political action. Our preparedness for such attacks is limited, which further emphasizes the need for reserve systems for critical functions, such as health care.

Vulnerability of Technical Systems: Summary of Experiences

- The dependence on advanced technical systems has increased the vulnerability of the community, including the health care system, to technical disturbances.
- Experiences show that such systems may fail during major incidents and disasters.
- To avoid fatal consequences of system failure, preparedness must include backup and reserve systems for critical functions, an area where much remains to be done.

2.4 Intentionally Caused Incidents

2.4.1 Armed Conflicts

Even if the current risk for a global war according to political experts seems to be small, armed conflicts are going on in many places in the world, as they have done as long as human beings have existed, and most likely will continue. Unfortunately development has gone toward an increasing involvement of civilian populations. To take care of those injured in armed conflicts – military as well as civilians – is an important task for medical staff. These are often situations in which available resources are insufficient for the immediate need of medical care, which by definition makes this field a part of major incident response.

From an organizational point of view, there is a difference between medical care during armed conflicts and medical care during "civilian" incidents: Armed conflicts rarely occur without warning, which gives time to plan and build up a good organization. On the other hand, this organization has to be in action for a long time, months or even years. In "civilian" incidents, there is often no warning at all and a community can be faced with a heavy load of severely injured only a few minutes after an alarm; however, the inflow of patients, in most cases, does not last more than 24 h, with the exception of a major incident level 3.

This difference requires different organizations, and a common mistake has been to build planning for major civilian incidents on military experiences, which not is relevant because it leads to an organization that takes too long to activate and includes components rarely needed in civilian major incident response. However, with this exception, military experiences are valuable for the management of "civilian" major incidents disasters, and research, education, and training in these fields should be closely linked. Armed forces also have good resources that should be prepared and available for use during major civilian incidents, which should be part of the planning on national and regional levels.

There are differences in the pattern of injuries between military and civilian trauma, but with global terrorism as the new threat, many injures traditionally considered to be military are seen after terror attacks and have to be treated by civilian staff. The principles for primary management of such injuries should, therefore, also be a part of education in disaster medicine.

The characteristics of war injuries and the principles of combat casualty management are described in a separate chapter in this book.

2.4.2 Terror Actions

Many consider the global terrorism as "the modern form of war," replacing the traditional armed conflicts. The tragic thing about terrorism is that it strikes blindly, with the aim to cause as much death and suffering as possible, regardless of whether those killed and injured are in any way involved in, or even aware of, the conflict behind the attack. This means that we as medical staff, wherever we live and work, at any time and without any warning can be faced with the task of taking care of large numbers of injured from a terror attack. Knowledge of the common pattern of injury in such incidents and how to deal with it is today an important part of education in disaster medicine.

Today we have to face the fact that it is possible for groups of people who want to cause biggest possible damage, death, and suffering to come into possession of harmful agents as weapon systems, chemical and toxic agents and microorganisms that can cause extensive damage even without access to advanced techniques of dispersion.

Global terrorism was forecasted to be the major disaster risk of the new millennium. Still, the World Trade Center disaster on September 11, 2001 (Pryor 2009) was a shock to many. It was a well-organized action with a global network and strong economy behind it. Three simultaneous attacks were performed, all using hijacked passenger aircrafts with innocent people aboard who were used as human missiles toward selected targets. The attack toward the World Trade Center in central Manhattan, New York, was successful, leading to 2,762 deaths when both towers collapsed. One thousand one hundred three injured needed hospital care; 29% of these were rescue staff and police that performed heroic efforts to save people from the inferno. The load of casualties on the extensive medical resources in New York was high, but not as high as expected because most of the severely injured died when the towers collapsed.

The central computer systems in New York City collapsed subsequent to the incident (Connocenti and Azima 2003), which seriously affected the involved hospitals, illustrating again the vulnerability of the health care system to technical disturbances (Fig. 2.7).

One of the three attacks, probably directed toward the White House in Washington, D.C., failed because the airplane crashed before reaching the target. However, the aim to kill all innocent passengers and crew on board was successful. The third attack, directed at the Pentagon, hit the target but did not get the desired effect because it hit a part of the building occupied by few people.

September 11 was the introduction to a series of extensive terrorist attacks in different parts of the world, and some of them deserve further description. In March 2004, a series of simultaneous bomb explosions hit four commuter trains in the center of Madrid, Spain (Turegano et al. 2008). Ten different bombs had been placed in backpacks or hand luggage in the different train wagons and were successively released by mobile telephones during a 3 min time period to create the biggest possible chaos. One hundred seventy-seven people were instantly killed. Seven hundred seventy-five injured were taken to the largest hospitals in Madrid; 263 of these had minor to moderate injuries whereas 512 needed more extensive treatment (Turegano et al. 2008).

Fig. 2.7 Two hijacked passenger aircraft operated by suicide pilots fly almost simultaneously into the two towers of World Trade Center in New York, New York on September 11, 2001. These crashes resulted in the death of more than 2,700 people, and more than 1,000 were injured and required hospital care (Photo Scanpix, with permission)

The terrorist attack in Madrid is still described as the most severe attack of this kind that has hit Europe, which is correct with regard to the number of dead. In July 2005 the next simultaneous attack hit London and has been described as the most extensive mass-casualty scenario in the United Kingdom since World War II (Aylwin 2006). In July 2007, in the middle of the time with the highest traffic intensity, three bombs were released simultaneously in three underground trains in central London. At the same moment, a fourth bomb was released on a bus close to a bus station. The total number of injured exceeded 750, but the number of dead was less than in Madrid. As in Madrid, those who died did so in immediate connection to the incident and the late mortality was quite low, probably because of good primary treatment and good triage.

The experiences from these two attacks, which have much in common, illustrate:

- Problems in *communication*, both within the prehospital organization and between the scene and the hospitals

- Initial "*over-triage*," with many patients in the prehospital phase given too high a priority
- Initial *maldistribution* of patients between hospitals because of failure in communication
- Initial *deficits in security*, with too many volunteer helpers initially involved
- Lack of *knowledge about blast injuries* among medical staff

Both of these incidents happened in major cities with good access to medical facilities of all kinds and staff with a high level of competence, probably contributing to the low rate of late mortality.

The London and Madrid attacks are examples of scenarios caused by physical violence. Terrorists also use other mechanisms of injury. In an attack on Tokyo's underground in March 1995, containers with the nerve gas *sarin* were placed in five wagons in three of the underground lines (Kulling 1998). The gas spread quickly, and within a short time alarms came from 15 different underground stations. A total of 6,000 people were exposed to the gas. Of these, 3,227 were taken to hospitals, altogether 493 were hospitalized in Tokyo's 41 hospitals. Twelve people died, ten as a direct consequence of the exposure and two from secondary brain injury. An additional number of patients developed secondary brain damage. Many of the rescue staff, working without personal protection, also developed symptoms after the exposure but had no fatal or persistent injuries.

Another terrorist scenario is the use of biologic agents. Soon after September 11, anthrax bacteria were intentionally spread in the US mail system. The consequences were able to be limited, but the treatment of bioterrorism is taken seriously all over the world. There are indications that cultures of bacteria against which we have no immunity are kept somewhere, and if organisms that cause diseases with relatively long incubation periods are taken into a country, they will have spread beyond control by the time they are discovered (Kyriacou 2006). The possibility that countries supporting terrorism will produce and use nuclear weapons has also been discussed as a possible disaster scenario.

In some countries, terror attacks are a part of the daily routine, with hundreds of people killed and even more injured every month. Because this is something that can happen any time in any part of the world, it is important that experiences from such countries is used for preparedness, education, and training in countries where terrorism is less frequent.

Terror Actions: Summary of Experiences

- Today, global terrorism constitutes perhaps our biggest risk for major incidents and disasters next to the big "natural disasters" and can, in contrast to natural disasters, occur at any time at any place in the world.
- It is today possible even for small groups of people to come into possession of systems or products with great potential to cause extensive damage, resulting in high numbers of dead and injured.
- Terrorism strikes with the aim to cause as much suffering and death as possible, regardless of whether the victims are totally innocent and not involved in, or even aware of, the reason behind the attack.
- This requires preparedness for these scenarios in all parts of the world as well as knowledge about the specific characteristics of these injures and their management as a part of education and training in disaster medicine.

2.5 Incidents Consequent to Changes in Nature and Climate

Incidents caused by changes in nature or climate can be categorized according to how quickly they hit us:

- *Sudden onset*: Incidents that hit us quickly with little or no warning, such as earthquakes, volcanoes, floods, and heavy winds (hurricanes, cyclones, tornadoes)
- *Slow onset*: Incidents that hit us more slowly and gradually, such as drought, starvation, and pandemics

2.5.1 Sudden-Onset Incidents

2.5.1.1 Earthquakes

During the last decades, almost 500,000 people have been killed and approximately three times as many have been injured in the most affected zones in the world. Examples of major earthquakes are Guatemala in 1970 with 67,000 dead and 143,000 injured, and China in 1976 with more than 200,000 dead. Usually the number of injured are three to four times the number of dead; for example, in Kobe, Japan, in 1995,

Fig. 2.8 The earthquake in the Sichuan Province in central China hit a densely populated area with extensive material destruction (**a**), including hospitals, which is why the initial medical resuscitation had to be performed under primitive conditions (**b**) (**a** Photo Scanpix, with permission; **b** from Wang et al. 2011, with permission)

5,300 were killed and 27,000 injured (Lorin et al. 1996). However, there are exceptions. In Armenia in 1988, 25,000 died, whereas the number of registered injured only was 30,000. These differences can be influenced by geographic differences but may reflect differences in the quality of primary management and triage.

Of major earthquakes during the last decade should be mentioned the one in Bam, Iran, in December 2003, which was caused by a shockwave of 6.5 on the Richter scale. More than 40,000 people were killed, approximately 30,000 were injured, and approximately 75,000 were left homeless. International assistance was provided by more than 60 countries from all parts of the world.

One of the most severe earthquakes in modern times occurred in May 2008 when the Sichuan province in China was hit by a shockwave of 7.8 on the Richter scale (Fan et al. 2011; Wang et al. 2011). Seventy thousand people died and more than five million lost their homes (Fig. 2.8).

In January 2010 the capital of Haiti, Port au Prince, was struck by a shockwave that measured 7.0 on the Richter scale (Missair et al. 2010). This earth quake affected a low-income country with a weak government and a weak infrastructure in the community. The most affected areas were densely populated, which resulted in a very high mortality. The estimated number of dead was approximately 200,000, and far more were injured. The already insufficient health care system could not cope with the extensive number of injured, and deficiencies and destruction of infrastructure (damaged roads and airports) made international support missions difficult. However, the international assistance was massive and approximately 50 foreign field hospitals arrived during the first 2 weeks. The United Nations cluster system was activated to coordinate the more than 300 health agencies active in the disaster zone. The lack of coordination was, as in all previous similar events, criticized, which illustrates the well-known need for better synchronization between supporting agencies based on need assessment and communication with the region receiving the support. This requires planning and preparedness on an international level "before it happens," which is a continuous challenge for coordinating organizations (Missair et al. 2010).

Also, many of the support actions during the aftermath of the Haiti earthquake have been criticized for insufficient attention to specific needs, both with regard to the situation in general and the pattern of injuries; the expression "disaster tourism" has been launched on the presumption that missions may be done with the aim to "learn and watch" more than to help. Even if such things may occur, it has to be emphasized that the vast majority of efforts are done with the best intentions to support suffering people. However, knowledge about how to handle the specific patterns of injuries met in these situations, and problems connected to this, is necessary for successful support missions, and this is an important part of education and training within this field. This is also the reason why a considerable part of this book is devoted to the primary management of injuries met in these situations.

It has been debated how big the need really is for urgent surgical procedures – for example, surgical teams or a field hospital – in situations like this, and many experiences indicate that such efforts almost always come too late to be of help during the acute phase. It is beyond doubt that most important are the resources already available on site and that external support must come quickly to be of value during this first phase. However, international support is of great value during the later *subacute phase*, with need for evacuation; protection; supplies of water and food; and to continue normal delivery of health care and replacing lost facilities and staff. International support is also needed during the *recovery phase* with rebuilding of the infrastructure and for education and training of local resources to increase the preparedness in zones hit by these kind of disasters.

The strategy of working in the acute phase, according to experience, should be a well organized response rather than rapid and poorly planned raids into the area with the risk of causing injuries to both rescue staff and victims. The scenario is often characterized by a primary flow of minor to moderate injuries first followed by the severe injuries that require time-consuming extrication.

2.5.1.2 Volcanoes

Volcano eruptions have hit human beings in all eras, and there are still active volcanoes in many places in the known risk zones for this type of disaster, including parts of Southern Europe and the United States. During recent decades, the population density around these areas has increased and buildings have gotten closer. For example, a new eruption of Mount Vesuvius in Italy is forecasted within the near future, and the difficulties of evacuating large populations from the risk zone is apparent because eruption can occur with little or no warning.

The scenario during volcano eruptions includes a broad spectrum of causes of injuries: different kinds of lava flow, some with high temperatures; landslides; toxic gases; secondary earthquakes; and floods. High doses of radiation (radon gas) have been registered in ash from volcanoes. All this means high demands on planning and preparedness in areas known as risk zones for eruptions.

The volcano eruption in Iceland in the early spring of 2010 illustrated a new problem that may occur during situations like this: the blocking of air traffic by clouds of volcano ash, which may have a devastating effect on international support actions when they are needed.

2.5.1.3 Tsunamis

When the tsunami disaster in December 2004 hit Southeast Asia, one of the biggest incidents in modern time, "tsunami" was for many an unknown term. This is remarkable because more people have died in floods and tsunamis than in earthquakes during the last part of the 20th century. Statistically, six major floods occur every century subsequent to earthquakes or landslides. Simultaneously, building activity increases close to the coasts; 35% of the world's population is today living within 100 km of a coastline. In the risk zones for floods, building has increased most.

What happened December 26, 2004, at 7:58 a.m. local time was that an earthquake, registering 9.3 on the Richter scale, occurred 30 km below the surface of earth, with an epicenter 240 km from the coast of Sumatra, Indonesia. The shockwave generated a flood with a maximal speed of 800 km/h, which hit the coasts of eight countries around the epicenter of the quake. The effect on the coasts varied with the distance and with the depth close to the coastline: In shallow waters, the wave could rise up to 10 m, thereby destroying everything up to several kilometers from the coast. In total almost 300,000 people died in the affected countries. In many countries, the infrastructure was totally destroyed and numerous people lost their homes and possibilities to earn their living.

For European countries, the effects in Thailand came into focus because many Europeans traditionally spent their Christmas holidays there. For example, 25,000 Swedish citizens were in Thailand at the time for the disaster. Five hundred forty-three of those were killed and 1,500 were injured. This created a new dimension of problems: taking care of large numbers of citizens who were injured and dead in a country far from home, which puts specific demands on authorities and health care; support of the host country in mediating contacts between victims and local health care; and evacuation of the injured to release pressure being placed on the local health care system (Fan et al. 2011). Previous experiences from such situations (Tran et al. 2003) have illustrated the importance of rapid deployment of assessment teams to the affected country to support these functions. Sweden was among the countries that did this much too slowly because of inability to make a rapid decision at a central level, which was heavily criticized in a parliamentary report (Lennquist and Hodgetts 2008). As a consequence, a special force is now always prepared to go instantly if something similar happens, and that has worked well in similar events after the 2004 tsunami. Because of increased traveling, many countries now have significant numbers of citizens who spend time in other countries. For Sweden, this has been calculated to be 400,000 at any time, which is between 4% and 5% of the whole population. Preparedness for scenarios like this is therefore mandatory.

This is one lesson from the 2004 tsunami disaster, but there is much more to learn from the experiences in Thailand that have been carefully evaluated. The load of casualties on the Thai hospitals was huge: the six hospitals in the Phuket and Phang Nga provinces received during the first 3 days more than 11,000 patients, 3,000 of whom needed in-hospital care (total capacity of beds in these hospitals was 1,500). In the 33 surgical theaters in these hospitals, 1,700 operations were performed during the first 5 days (Lennquist and Hodgetts 2008).

In spite of this, the in-hospital mortality could be kept low. The major contributing factor to this was good preparedness for major incidents and disasters. An air bridge with supplies of materials and staff from Bangkok to Phuket was planned and could start immediately at the time of the disaster. Casualties were evacuated to Bangkok on returning flights. All hospitals had functioning and recently tested disaster plans, including prepared areas for primary triage, triage tags, prepared rooms for coordinations and command on both hospital and regional levels. The number of surgical theaters was extended by using prepared rooms for minor surgery with local anesthesia (Lennquist and Hodgetts 2008).

With regard to hospital beds, the experiences confirmed what has been shown in many major incidents and disasters during recent years: The beds are not the limiting factor; room to place patients can always be found if all staff is mobilized. Limiting factors for surge capacity are ventilators, operation theaters, and supplies.

One initial mistake occurred: the primary closure of wounds. The majority of surviving injured had wounds, and these were caused by considerable energy (Fig. 2.9a, b), were severely contaminated, and came late to treatment, indicating that they should have been treated like war injuries and primarily left open for delayed primary closure. Because staff of all categories had to be involved in wound treatment, this was not generally understood from the beginning, and the incidence of infections, many severe, was high. When this was discovered, the policy was immediately changed and infections went down. This illustrates one important thing: The principles for primary management of injuries should be known by all medical staff, and this

Fig. 2.9 The Tsunami disaster in Southeast Asia in December 2004 hit many countries, among them Thailand, where many European tourists spend their Christmas holidays. Many families with children were living in resorts close to the waterfront (**a**). In this area, because of the shallow water outside the beaches, the tsunami waves reached a height of 10 m, and because of the flat land in some places they reached more than 4 km from the waterfront, destroying everything in their way (**b**). In total, 300,000 people died in the eight countries hit by the Tsunami; of those, more than 8,000 were dead or missing in Thailand, many of them tourists

is an important part of education in disaster medicine (Edsander-Nord 2008; Kespechara et al. 2005).

On March 11, 2011, Japan was hit by the worst disaster since World War II. An earthquake with the magnitude of 9.1 on the Richter scale occurred in the ocean outside the city of Sendai at the northwest coast of Oshus. The earthquake was of the same magnitude as the one outside the cost of Sumatra in December 2004 and was one of the five biggest ever registered. A tsunami wave, growing to at least 10 m in height as it approached the coastline, was generated by the earthquake and had a devastating effect on the cities and villages along this coastline (Fig. 2.10). In spite of a good tsunami warning system and extensive work on protective walls, the tsunami wave caused the loss of at least 10,000 lives; the confirmed number of dead when at the time of this writing was approximately 8,500, but almost 10,000 people are still registered as missing and the rescue work in the affected areas is difficult because of the extensive destruction.

As already mentioned in the section "Accidents Caused by Radiation," some of the nuclear plants at the coastline were hit by the wave, resulting in the destruction of the reserve system for cooling the plants in case of an incident. This resulted in overheating, with potential meltdown and leakage of radiation (Fig. 2.11), and more than 200,000 people had to be evacuated. As mentioned above, both short-term and

Fig. 2.10 (**a**, **b**) On March 11, 2011, Japan was hit by an earthquake with a magnitude of 9.1 on the Richter scale off the coast of Sendai. The earthquake generated a tsunami wave rising up to a height of 10 m or more when it hit the coastline with devastating effects. Despite a good tsunami warning system and protection walls, the wave took at least 10,000 lives (preliminary figure; the final death toll is expected to be double this) (Photo Scanpix, with permission)

long-term consequences of this are at the present time difficult or impossible to estimate, but they may influence both economy and public health not only in Japan but also in other countries.

2.5.1.4 Floods

Floods constitute more than 50% of all incidents caused by changes in nature and climate and cause more deaths than any other type of such incidents.

Fig. 2.11 Some of the nuclear plants at the coastline were hit, and the reserve system for cooling in case of an incident was destroyed, leading to overheating of the plant and leakage of radioactive material. Picture from Fukushima nuclear plant (Photo Scanpix, with permission)

Including floods caused by tsunamis and heavy winds, these kinds of disasters are responsible for 75% of all disaster-related deaths. The major cause of death is drowning, and the number of survivors is small in comparison to the number of dead. Secondary injuries and diseases subsequent to contaminated water and toxic substances, on the other hand, commonly occur after major floods. That was also shown clearly after the tsunami disaster (Edsander-Nord 2008; Kespechara et al. 2005).

The rescue actions during these types of disasters are demanding and require preparedness for evacuation of large numbers of people and management of problems related to impaired or destroyed infrastructure in the affected communities.

An example of such an incident hitting a technically advanced community, leading to severe consequences, is the flood after the hurricane Katrina in the United States in 2005; New Orleans, Louisiana was hit especially hard (Zoraster 2010; Condon et al. 2010). The hurricane itself caused rather moderate damage to the city of New Orleans. However, the water in the Mississippi River rose and broke the walls protecting large parts of the area around the city, resulting in flooding of large parts of living areas. Many people died by drowning, but many also died waiting for help, sitting on roofs without electricity and water in the high temperature and humidity. Because this happened in one of the richest and technically best developed countries in the world, it caused severe criticism against the way it was handled by the authorities responsible. Hesitation to send rescue units into the area because of the risk of losing them has been reported as one of the reasons for the delay in rescue operations. With the expected global elevation of water levels, floods like Katrina can in the future be a potential threat in many parts of the world.

2.5.1.5 Heavy Winds

There is today an increasing agreement that climatic changes caused by the human influence on nature have generated an increased risk of atmospheric disturbances in the form of cyclones, hurricanes, and tornadoes. This also means that countries that so far have not been hit by this kind of phenomenon are at increased risk in the future.

Incidents caused by heavy winds induce the most extensive material destruction and the biggest risk for disturbances in infrastructure (roads, water, electricity, and telecommunication). However, the number of dead and injured directly caused by the influence of wind is often limited. The most important with regard to health care planning is good preparedness to maintain function for long periods of time without external supplies of water and/or electricity, which means accurate and sufficient reserve systems.

2.5.2 Slow-Onset Incidents

2.5.2.1 Drought and Starvation

As mentioned above, the global population has increased from 1.5 to 6 billion during the last century and continues to increase. This increase occurs most often in countries and regions that already have difficulties feeding their existing populations. Drought and dearth of foodstuffs can have fatal consequences for large populations in such areas, of which the starvation disasters in Africa during recent decades are terrifying examples. It is the obligation of rich countries to assist economically and technically, but armed conflicts and political tension can make this difficult. It is important that international relief operations are well coordinated and are adapted to the real needs of the suffering populations. This is a field in which much still remains to be done.

2.5.2.2 Pandemics

"Incidents caused by nature" can also be defined those caused by the spread of contagious diseases. Sudden spread of microorganisms against which we have no immunity or resistance have occurred throughout history at regular intervals and have caused large numbers of deaths, and this remains a potential threat. With the increased global population, increased concentrations of people in limited areas, and increased global travel, such pandemics are likely to cause even more fatal effects than those previously. This requires preparedness to prevent the spread of such pandemics through early diagnosis and preventive measures such as information and vaccination. Chap. 12 in this book is dealing specifically with this part of disaster medicine.

2.5.2.3 Complex Emergencies

Slow-onset incidents, including many of the components above (political or armed conflicts, refugees, displaced populations, lack of food and water, pandemics), have been defined as complex emergencies, requiring a multidisciplinary approach, special organization, and special knowledge. This is outside the scope of this book, but literature for further reading in this field is given below (see also Chap. 13).

2.6 Conclusions

This overview, with examples of major incidents and disasters during recent decades and examples of what we can learn from them, clearly illustrates what also has been shown statistically: we are faced with increasing risks of such events. A significant part of this is the price we have to pay to live in the way we do. It should then also be our obligation to, as much as possible, reduce the consequences of this – death, illness, and suffering.

All experiences show that we can do that in many ways:

- Identification of risks
- Prevention
- Planning
- Preparedness
- Education and training
- Development and research

Awareness of the importance of these measures has increased worldwide, mostly because of development during recent years. The scientific field of major incidence response, *Disaster Medicine* (Chap. 19), is still a young field within medicine, but is today recognized and established in most countries with major emphasis on education and training at all levels. However, we also need methodological development and research, a field in which we are still only at the beginning. Methodology in education and training, and important fields for scientific development and research, is dealt with in Chap. 18 in this book.

References to Major Incidents and Disasters

The references below refer in alphabetic order to the examples of different major incidents described in this chapter to facilitate further studies for those interested.

Some of these references refer to Kamedo reports. "*Kamedo*" *is the Swedish Disaster Medicine Organization Committee with the task of sending observers to the sites of major incidents to collect information as a basis for published reports. The reports listed below are all printed in English, some them only as extended summaries, but upgrading is planned. They can be downloaded free of charge and are available in printed form and can be acquired from the Swedish National Board of Health and Welfare's website*: http://www.socialstyrelsen.se. *Search "English - Kamedo" and then search for the publication number only or from the given list.*

Almersjö O, Kulling P (1994) The tram accident in Gothenburg, March 12, 1992. Kamedo report 62, 2

Almersjö O, Ask E, Brandsjö K et al (1993) The fire on the passenger liner Scandinavian Star, April 7, 1990. Kamedo report 60, 3

Arturson G (1981) The los Alfaques disaster: a boiling liquid expanding vapor explosion. Burns 7:233–251

Arturson G (1987) The tragedy of San Juanico – the most severe LPG disaster in history. Burns 13:87–102

Arturson G, Lorin H, Olofsson P et al (1994) The Jumbo jet crash in Amsterdam, October 4, 1992. Kamedo report 64, 16
Aylwin CJ (2006) Reduction in mortality in urban mass casualty incidents – analysis of triage, surgery and resources use after the London bombings on July 7, 2005. Lancet 368:2219–2225
Baxter PJ (1990) Review of major chemical incidents and their medical management. Royal Society of Medicine Services, Ltd., London, pp 7–20
Becker WK, Waymack JP, Mc Manus AT et al (1990) Bashkirian train pipeline disaster: the American military response. Burns 16:325–328
Berg-Johannesen K, Stefanini S, Lundin T et al (2006) Impact of bereavement among relatives in Sweden and Italy after the Linate airplane disaster. Int J Disaster Med 4:110–117
Bledsoe B, Smith M (2004) Medical helicopter accidents in the United States – a 10-year review. J Trauma 56:1325–1328
Brandsjö K, Reizenstein P, Walinder G (1992) The nuclear power plant accident in Chernobyl, April 26, 1986. Kamedo report 59, 4
Brandsjö K, Häggmark T, Kulling P et al (1997) The Estonia disaster: the loss of the M/S Estonia in the Baltic, September 28, 1994. Kamedo report 68, 15
Brismar B, Lorin H (1990) The accident at the Ramstein Base Air Show, August 28, 1988. Kamedo report 57, 31
Buerk CA, Batdorf JW, Cammack KW et al (1982) The MGM Grand Hotel fire – lessons learned from a major disaster. Arch Surg 117:641–644
Cassuto J, Tarnow P (2003) The discotheques fire in Gothenburg 1998 – a tragedy among teenagers. Burns 29:405–416
Condon S, Savoia E, Cardigan RO et al (2010) "Operation helping hands" – Massachusetts' health and medical response to Hurricane Katrina. Prehosp Disaster Med 25:80–86
Connocenti P, Azima C (2003) Computer vulnerability, consequences and preparedness – experiences from the World Trade Center disaster. Int J Disaster Med 1:69–73
Eckerman I (2005) The Bopal Saga – causes and consequences of the world's largest industrial disaster. Universities press, India
Edsander–Nord Å (2008) Wound complications from the Tsunami disaster – a reminder of indications for delayed closure. Eur J Trauma Emerg Surg 34:457–464
Fan Z, Li A, Lian B et al (2011) Injury type and victims in the 12 May 2008 Wenchuan earthquake: analysis of 1,038 patients in Jiangyou City. Eur J Trauma Emerg Surg 37:3–7
Fries H (1991) The airplane fire in Manchester, August 22, 1985. Kamedo report 58, 14
Hallén B, Kulling P (1990) The fire at the King Cross underground station, November 18, 1987. Kamedo report 56, 30
Hülse E, Oestern HJ (1999) Die ICE Katastrophen von Eschede – eine interdisciplinäre analyse. Springer, Berlin
Kespechara K, Koyosombat T, Pakmol S et al (2005) Infecting organisms in victims from the Tsunami disaster. Int J Disaster Med 1:66–70
Kulaypin AV, Sakhautdiov VG, Temerbulatov VM et al (1990) Bashkiria train – gas pipeline disaster: a history of the joint USSR/USA collaboration. Burns 16:339–342
Kulling P (1998) The terrorist attack with Sarin in Tokyo, March 20, 1995. Kamedo report 71, 20
Kyriacou DN (2006) Anthrax – from antiquity and obscurity to a front runner in bioterrorism. Infect Dis Clin North Am 20(2):227–235
Lee CY, Davis T (2006) Building collapse. In: Ciottone GR et al (eds) Disaster medicine, 2nd edn. Kluwer/Lippincott, Hingham/Philadelphia, pp 842–845
Lennquist S, Hodgetts T (2008) Evaluation of the response of the Swedish Health Care System to the Tsunami disaster in Southeast Asia. Eur J Trauma Emerg Surg 34:465–485
Lorin H, Norberg KA (1998) The ferry accident at Zeebrügge, March 6, 1987. Kamedo report 55, 17
Lorin H, Unger H, Kulling P et al (1996) The great Anshin-Awaji (Kobe) earthquake, January 17, 1995. Kamedo report 66, 12
Melville LD, Rahman-Kahn N (2006) Bridge collapse. In: Ciottone GR et al (eds) Disaster medicine, 2nd edn. Kluwer/Lippincott, Hingham/Philadelphia, pp 846–849
Missair A, Gebbard R, Pierre E et al (2010) Surgery under extreme conditions in the aftermath of the 2010 Haiti earthquake. Prehosp Disaster Med 25:487–493
O'Hickey SP, Pickering CA, Jones PE et al (1987) Manchester air disaster. Br Med J 294:1663–1667
Pryor JP (2009) The 2001 World Trade Center disaster – summary and evaluation of experiences. Eur J Trauma Emerg Surg 3:212–224
Tran M, Garner A, Morrison I et al (2003) The Bali bombing – civilian aeromedical evacuation. Med J Aust 179:335
Turegano F, Perez-Diaz D, Sanz-Sanchez M et al (2008) Overall assessment of of the response to the terrorist bombings in trains in Madrid, March 11, 2004. Eur J Trauma Emerg Surg 34:433–441
Wallace AW, Rowles JM, Colton CL (1994) Management of disasters and their aftermath. BMJ Publishing Group, London
Wang Z, Sun Y, Wang Q et al (2011) Anesthetic management of injuries following the 2008 Wenchuan earthquake. Eur J Trauma Emerg Surg 37:9–12
Zoraster RM (2010) Vulnerable populations: Hurricane Katrina as a case study. Prehosp Disaster Med 25:74–79

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