10. Technological and natural hazards

Technological accidents continue to occur in Europe, but those that involve large numbers of fatalities have decreased during the past decade, with the exception of mining disasters in Ukraine. The apparent increase in the total number of major accidents in the European Union since 1985 may be due to improved reporting as well as increases in industrial and other economic activities.

Natural disasters continue to have a far greater impact than technological accidents. Both the probability of occurrence and the consequences of natural disasters can be increased as a result of technological advances and human activities such as agriculture and forestry.

A holistic approach to hazard management, based on lessons learned from past accidents and natural disasters, recognition of the need for better emergency planning, and implementation of a number of EU directives, should help to reduce the numbers and consequences of technological accidents and reduce the impacts of some natural disasters.

10.1. Introduction

Major technological accidents continue to occur, even with advances in the safety management of hazards. Technological accidents claim only a fraction of the lives lost as a result of natural hazards (approximately 5 % of the total in the period 1985–96 in Europe). For both technological accidents and natural hazards, the risk depends on where people live. The explosion in the outskirts of Toulouse in September 2001 tragically illustrated the capacity of technological accidents to claim many lives.

The catastrophic earthquake in Turkey in 1999 demonstrated that human life remains vulnerable to the violent effects of nature. Natural catastrophes continue to have a far greater effect, in terms of fatalities, injuries and overall cost, than technological accidents. Flooding, landslides, avalanches and violent storms are all capable of causing multiple fatalities in one event, although none can match earthquakes for sheer numbers of fatalities. The costs of storms and flooding incidents can run into billions of euros.

The risk of fatality from natural hazards depends, to a large extent, on where people live. The seismically active areas in Europe are well documented, the location of volcanoes is known and the areas susceptible to flooding, landslides and avalanches can generally be predicted. However, there is still an element of unpredictability about when and exactly where such events will happen. All these can take people by surprise, as their onset may be very rapid.

Technological advances and human activities may be exacerbating the impacts of natural hazards, both at a chronic and an acute level. The apparent increase in flooding incidents seen across Europe in the past decade may be linked to chronic changes to the environment caused by human activities, such as global warming. Activities such as land clearing for agricultural purposes have been a cause of catastrophic landslides following periods of heavy rain.

For technological hazards and those activities that may exacerbate the effects of natural hazards, design evolution and operational experience have reduced the risk levels over the years. ‘Holistic’ approaches, which take an integrated perspective, are becoming more prevalent, with increasing attention to the reduction of risk of long-term environmental impact as well as acute health and property damage from accidents. However, there remains a residual risk that must be well managed at all times. This is particularly the case for those hazards that may have devastating consequences for a large number of people, such as serious nuclear accidents. Large-scale preparations are being considered for the various natural hazards so that the response is rapid and well coordinated to minimise the harmful effects.

10.2. Technological hazards

10.2.1. Industrial accidents

Between 1971 and 1992 there was, on average, one technological accident every year in Europe that resulted in 25 or more fatalities (Table 10.1). Thereafter, there were no accidents resulting in 25 or more fatalities until 1998 (although no data were available

Table 10.1. **Industrial accidents resulting in more than 25 fatalities (since 1971)**

Year	Location	Products involved	Type of accident	Fatalities
1971	Czechowice, Poland	Oil	Explosion	33
1971	English Channel	Petrochemicals	Ship collision	29
1973	Czechoslovakia	Gas	Explosion	47
1974	Flixborough, UK	Cyclohexane	Explosion	28
1976	Lapua, Finland	Gunpowder	Explosion	43
1978	San Carlos, Spain	Propylene	Fireball (road transport)	216
1979	Bantry Bay, Ireland	Oil, gas	Explosion (marine transport)	50
1979	Warsaw, Poland	Gas	Explosion	49
1979	Novosibirsk, USSR	Chemicals	Unknown	300
1980	Ortuella, Spain	Propane	Explosion	51
1980	Rome, Italy	Oil	Ship collision	25
1980	Danaciobasi, Turkey	Butane	Unknown	107
1982	Todi, Italy	Gas	Explosion	34
1983	Istanbul, Turkey	Unknown	Explosion	42
1984	Romania	Chemicals	Unknown	100
1985	Algeciras, Spain	Oil	Transhipment	33
1986	Chernobyl, USSR	Nuclear	Reactor explosion	31*
1988	Arzamas, USSR	Explosives	Explosion (rail transport)	73
1988	North Sea, UK	Oil, gas	Fire	167
1989	Acha Ufa, USSR	Gas	Explosion (pipeline)	575
1991	Livorno, Italy	Naphtha	Transport accident	141
1992	Corlu, Turkey	Methane	Explosion	32
1998	Donetsk, Ukraine	Methane	Explosion (mine)	63
1999	Zasyadko, Ukraine	Methane	Explosion (mine)	50
2000	Donetsk, Ukraine	Methane	Explosion (mine)	81
2001	Donetsk, Ukraine	Coal dust/methane	Explosion (mine)	36
2001	Toulouse, France	Ammonium nitrate	Explosion	31
2002	Donetsk, Ukraine	Methane	Explosion (mine)	35

Notes: Other events may have occurred that have not been widely documented.
* Number of fatalities related directly to the explosion of the reactor; see Section 10.3.3 on fatalities from the effects of the accident.

Sources: UNEP, 2002a, 2002b; BBC, 2002a

for 1998 and 1999 on the UNEP database (UNEP, 2002a; 2002b) and the data were derived from isolated sources). It would appear that, in general, accidents involving large numbers of fatalities have decreased in the past decade, with the exception of methane explosions in Ukrainian mines.

There is generally an equal spread between those events that occurred in the European Union (EU) and those in eastern Europe, although before the fall of the 'Iron Curtain' there may have been a number that were not widely reported. In recent years, however, there have been disproportionate numbers of multiple-fatality accidents in Ukrainian mines (see Box 10.1). One of the major reasons for this is a lack of investment, compounded by poor safety and environmental management. This is a common theme that runs through many technological industries in eastern European countries, certainly when compared to western Europe.

Many countries in Europe have used the EU Seveso II directive as a model and this should help to decrease the number of major accidents. It is anticipated that this will bring consistent standards and an improvement in safety performance throughout Europe.

The total number of major accidents reported each year in the EU from 1985 to 1999 shows a steady increase, with the maximum number reported during 1998 (Figure 10.1). This may be due to a number of factors, including increased industrial and other economic activity and increased population densities around potentially hazardous sites, only partly compensated for by increased awareness and safety measures (see Box 10.2). The rapid rise in the number of accidents in the first few years of the MARS (major accident reporting system) database may have been due to better reporting. Many companies are now using the data from accidents to help understand their underlying causes, such as management failure. This learning exercise is one element of an improved approach to safety and environmental management that is being used by organisations in general, following the advent of the Seveso II directive.

When analysing the causes of major accidents, by far the biggest immediate cause is mechanical failure. Operator error is also a significant contributor (Figure 10.2). Both these are likely to be due to some kind of management failure, which is thus the underlying cause. For example, a failure due to corrosion may have been caused by a lack of monitoring. In fact, for 67 % of the accidents reported in the MARS database, the dominant underlying causes were poor safety and environmental management (Drogaris, 1993; Rasmussen, 1996). The Seveso II directive puts emphasis on mechanisms for the prevention of accidents, such as good safety management; this is a major improvement from the earlier Seveso directive.

10.2.2. Pipeline accidents

The impacts of pipeline accidents are usually only environmental, i.e. release of hydrocarbon liquid to surface waters and groundwater and release of gas to the atmosphere. There have been no recorded fatal accidents following gas releases from transmission pipelines over the period 1970–2000 in those countries included in the EGIG (European Gas pipeline Incident data Group) database (all within western Europe, see Figure 10.3). However, fatal accidents can certainly occur, as illustrated by an

Box 10.1. Ukraine's troubled mines

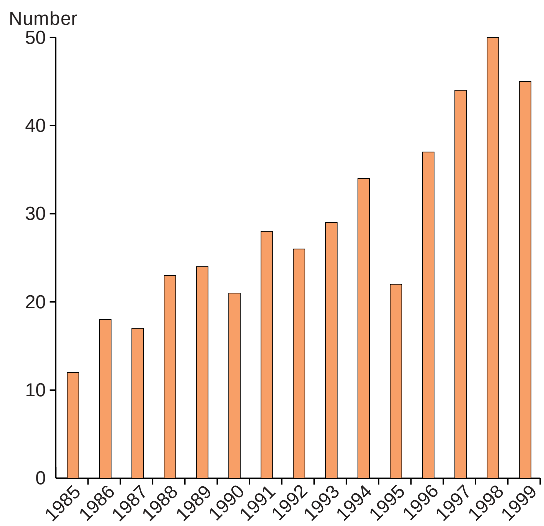
Ukraine has the world's highest coal industry death rate, with an average of about 300 deaths per year. In recent years, there have been several multiple-fatality accidents. Funding cuts since the break-up of the USSR in 1991 have forced the industry to struggle for survival and have led to a neglect of safety. Even in Soviet times, working practices were shoddy and safety standards low.

Underground explosions are common and are the main cause of fatalities, usually caused by methane that builds up in poorly ventilated shafts. Other deaths have been caused by roof collapses or the breakdown of ventilation systems. Equipment is outdated and often faulty; exposed wires can set off explosions, gas sensors and oxygen tanks do not work, and pit props are broken.

The majority of the mines are uneconomic, only 50 of more than 200 are viable. This, combined with very poor safety management, has led to the multitude of tragic accidents.

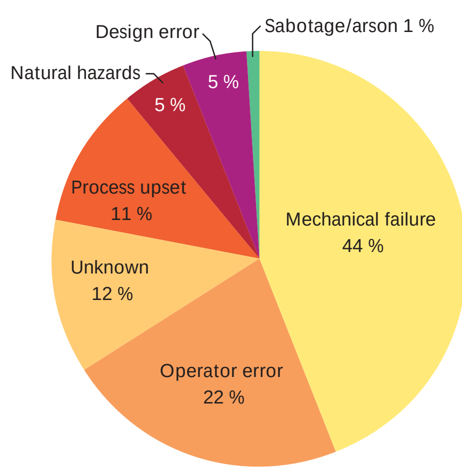
Source: BBC, 2000

Number of major accidents reported on the MARS database (EU) Figure 10.1.



Source: MARS database, 2002

Causes of major accidents in the process industries Figure 10.2.



Source: J&H Marsh & McLennan, 1998

Box 10.2. Ammonium nitrate explosion in Toulouse, France, 2001

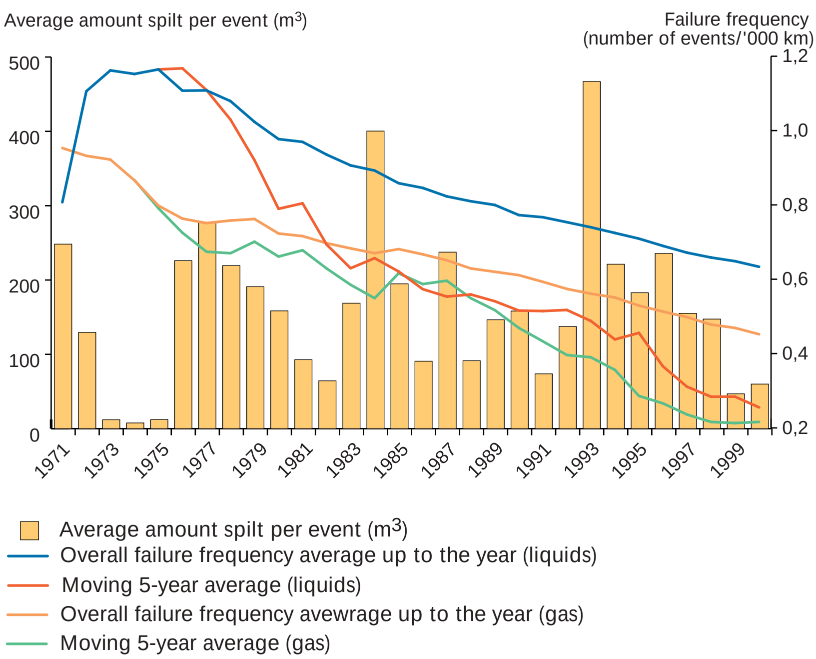
On 21 September 2001, a huge explosion ripped through the AZF fertiliser factory in an industrial zone on the outskirts of Toulouse, France, leaving a 50 m diameter crater more than 10 m deep. Thirty-one people were reported dead, including some outside the plant, and 2 442 were injured. More than 500 homes were made uninhabitable and almost 11 000 pupils were kept at home after some 85 schools and colleges were damaged. Windows in the city centre 3 km away were blown out.

The explosion occurred in a warehouse in which granular ammonium nitrate was stored. Ammonium nitrate can explode under certain conditions. These must include added energy (heat, shock), especially under conditions of confinement or in the presence of contaminants. Although ammonium nitrate is generally used safely and is normally stable and unlikely to explode accidentally, accidental explosions of ammonium nitrate have resulted in loss of life and destruction of property.

The AZF plant was opened in 1924 in what was then countryside, but the urban sprawl from Toulouse (population 700 000) led to homes being built closer and closer to the plant. The AZF site is one of 1 250 factories in France classified as high risk. The site falls under the rules of the Seveso II directive.

Source: UNEP, 2002c

Figure 10.3. **Pipeline accidents and average amount spilt in western Europe**



Sources: CONCAWE, 2002; EGIG, 2002

accident near Ufa, Russia, on 4 June 1989, when two trains, each carrying more than 500 passengers, passed each other within a cloud of natural gas arising from a pipeline leak (see Table 10.1). The gas exploded and most of the passengers in one train were killed outright; hundreds of passengers in the other (many of them children) suffered severe burns. This was not an isolated incident. The *Oil and Gas Journal* in 1993 reported that Russian oil and gas pipelines are plagued by accidents, citing an example of a major pipeline break in western Siberia in 1993 when more than 2 000 m^3 of crude were lost. More and more new pipelines are being constructed to transport oil and gas to the west from the new frontiers in the east, such as the Caspian region and Siberia.

The failure rate of liquid and gas pipelines in the EU since 1971 shows a significant downward trend, which is a reflection not just of better design and construction, but also of the improved safety management of existing pipelines, for example with improved corrosion protection and monitoring systems. In particular, there has been a marked improvement in the five-year moving average failure rate in both types of pipeline, with a four to fivefold decrease in the rate since records began. However, there has been no general decrease in the average amount spilt per event.

10.2.3. Oil spills

Another major hazard where the impact is predominantly environmental is marine oil spills. Worldwide, the annual number of oil spills and the total oil spilt from tankers shows a downward trend despite increasing maritime transport of oil, although the rate of improvement has decreased since about 1980 (Figure 10.4). European figures generally reflect the world situation; for the EU, for instance, tanker oil spills continue, although both the frequency and the amounts involved have fallen over the past decade. The erratic occurrence of such accidents, however, is illustrated by the recent Prestige disaster off the west coast of Spain.

Tanker safety is a major issue on the International Maritime Organisation's (IMO) protection agenda. In 1992, the IMO mandated the phasing out of conventional, single-hulled tankers. By 2010, all tankers and super tankers carrying crude oil must have double hulls; this will reduce the likelihood of spills. For spills greater than 700 tonnes, about 77 % are due to collisions, groundings and hull failures (Figure 10.5). Double hulls should reduce the frequency of such spills, so a further decrease in large spills worldwide, including in European waters, is expected.

However, the *Prestige* accident on 13 November 2002 has highlighted the potential environmental impact that oil transportation still poses. The *Prestige* suffered hull damage in heavy seas off northern Spain and developed a severe list.

She was taken in tow and moved away from the coast, but eventually broke in two and sank in just over 3 km of water. She was carrying a cargo of some 77 000 tonnes of heavy fuel oil, some of which was lost at the time of the initial damage and more subsequently (ITOPF, 2002b).

Oil released before the vessel broke in two came ashore intermittently along the predominantly rocky coastline between Cabo de la Nave and Punta Langosteira in northwest Spain, a distance of 100–150 km and reached French coasts later on. The affected area supports a rich and diverse fishing and aquaculture industry, including the cultivation of mussels, oysters, turbot and several other species, and the harvesting of various 'wild' species of fish and shellfish. The adverse social and economic effects may be felt for many years.

Since this disaster, the European Commission has accelerated tanker safety measures. It has published a blacklist of 66 ships deemed too dangerous for European waters, 16 of which are oil and chemical tankers. France and Spain agreed to check all ageing single-hulled vessels in their waters and force them out if necessary. They have adopted the emergency measures introduced by the EC without waiting for the rest of the EU to endorse them (BBC, 2002b).

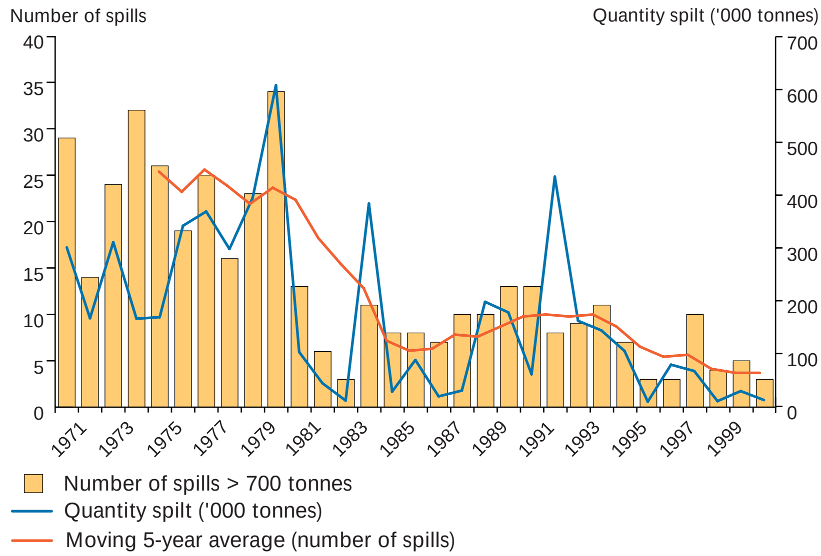
10.2.4. Tailings dam failures

A number of tailings dam failures that have led to pollution of surface waters and widespread fish kills have occurred in recent years (Table 10.2.). As with industrial accidents, these have occurred with almost equal frequency in EU and eastern European countries. The incident at Stava, Italy, in 1985 claimed the lives of 268 people. The most devastating incident environmentally was that in Baia Mare, Romania, in 2000, where the release of highly toxic cyanide resulted in the killing of tonnes of fish and the poisoning of potable water for more than 2 million people in Hungary. Such an incident could occur in many areas across the whole of Europe, since the use of cyanide is still the preferred method for processing gold ores.

Another major cause of surface water pollution is firewater runoff following major incidents involving toxic substances. This is best illustrated by the warehouse fire at the Sandoz plant near Basel, when many toxic substances in the firewater flowed into the Rhine and caused the death of almost all aquatic life as far as 100 km downstream. Similar incidents could occur across the whole of Europe unless precautions are taken to contain and treat firewater onsite.

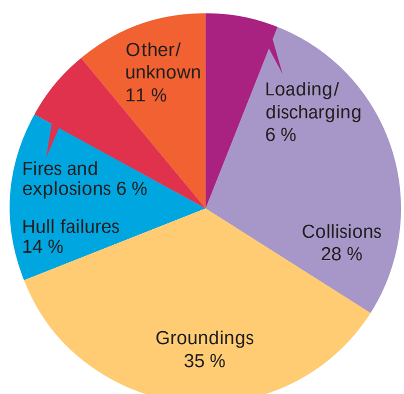
Directive 2000/60/EU of the European Parliament and the Council, establishing a framework for Community action in the field of water policy, entered into force on 22 December 2000. Among its central aspects was an obligation to progressively reduce discharges, emissions and losses of hazardous substances, including those due to accidents.

Number of oil spills worldwide and total oil spilt, 1970–2000 Figure 10.4.



Source: ITOPF, 2002a

Causes of oil spills 1974-2000 (spills greater than 700 tonnes) Figure 10.5.



Source: ITOPF, 2002a

Table 10.2. **Tailings dam failures since 1980**

Source: UNEP, 2001

Date	Location	Release	Impacts
20 Jan 1981	Lebedinsky, USSR	3.5 million m^3	Tailings travelled distance of 1.3 km
15 Sep 1983	Stebnik, Ukraine	1.2 million m^3 of brine	Dnestr river polluted for hundreds of km, damaging the fish resources and biodiversity of the river
19 Jul 1985	Stava, Trento, Italy	200 000 m^3	268 people killed
1 Mar 1992	Stara Zagora, Bulgaria	500 000 m^3	Not known
1 May 1996	Sgurigrad, Bulgaria	220 000 m^3	The tailings wave travelled 6 km and destroyed half of a village 1 km downstream, with 107 victims
25 Apr 1998	Aznalcóllar, Spain	4-5 million m^3 of toxic water and slurry	Thousands of hectares of farmland covered with slurry and water contamination in national park of Doñana
31 Dec 1998	Huelva, Spain	50 000 m^3 of acidic and toxic water	The liquid spilled into Ría de Huelva, a tributary of Río Tinto
30 Jan 2000	Baia Mare, Romania	100 000 m^3 of cyanide-contaminated liquid (105-110 tonnes equivalent of cyanide)	Contamination of the Somes/Szamos stream, tributary of the Tisza River
10 Mar 2000	Borsa, Romania	22 000 tonnes equivalent of heavy-metal contaminated tailings (70-100 tonnes equivalent of copper)	Contamination of the Vaser stream, tributary of the Tisza river
8 Sep 2000	Gällivare, Sweden	1.5 million m^3 of water carrying some residual slurry	The bed of the Vassara river was covered over a length of at least 7–8 km with a white slurry

10.3. Nuclear hazards

10.3.1. Nuclear power stations

Apart from the 1986 Chernobyl accident (see Section 10.3.3) other accidents have occurred in Europe over the past 40 years. Some of these have had environmental consequences and a handful have resulted in loss of life, although all have been minor compared with the effects of Chernobyl. A review of nuclear accidents up to 1996 has shown a highly disproportionate number of accidents in the former Soviet countries.

Figure 10.6 shows the number of nuclear power reactors currently operating (research reactors are not included). France, which has the most reactors of any one nation, has had only a small number of minor incidents. The Russian Federation, which has half the number of reactors, has had a multitude of incidents. This distinction between eastern and western Europe is mirrored by the other nations, suggesting a lower level of safety standards in the east.

Since 1970, the number of nuclear installations in Europe has increased and many European countries now have nuclear reactors at or towards the end of their working lives, as shown in Figure 10.7. It can be seen that there will be an increasing number of old reactors operating in Europe. At present, the United Kingdom is the only nation with a number of operational reactors above 36 years old and thus the United Kingdom has a significantly disproportionate number of old reactors at the end of their working lives.

It should be noted that in recent years, the safety of Soviet-designed reactors has improved. This is due largely to the development of a culture of safety encouraged by increased collaboration with western Europe countries, and substantial investment in improving the reactors. Since 1989, more than 1 000 nuclear engineers from the former USSR have visited western nuclear power plants and there have been many reciprocal visits, with more than 50 twinning arrangements put in place (UIC, 2001).

However, accidents at a number of nuclear plants have led to low public confidence in

Box 10.3. Hazards linked to armed conflicts

Recent evidence suggests that military activities are among the world's most environmentally destructive activities. The environmental impacts of war begin with disturbance and destruction of natural habitats, and progress to contamination of land, air and water with the wastes of people and machines. In most war zones, the impacts on the environment are long term or permanent.

Preparation
Military bases require large areas of land and often lead to the permanent destruction of flora and fauna. Large sectors of most countries are reserved for military exercises, which may include some related to chemical and biological warfare. In countries that manufacture weapons, areas may be used for testing missiles, chemical and biological warfare products, and nuclear weapons. All of these activities severely degrade natural ecosystems and tend to be treated as exceptions to any environmental regulations.

Conflict
As seen in the recent conflicts in the Balkans, human deaths and the destruction of 'military targets' are not the only immediate consequences of war. Modern weapons rely on toxic chemicals for much of their explosive force and propulsion. Hence they create negative environmental impacts through their own composition as well as their destructive power. When a heavy bomb goes off, it creates temperatures of approximately 3 000 ºC; this not only annihilates all flora and fauna but also destroys the lower layers of soil, which can take anywhere between 1 000 and 10 000 years to regenerate.

Although the weapons constitute the most obvious threat to the environment, the targets that they destroy are also a highly significant contributor to the environmental devastation of war. Hazardous materials such as fuels, chemicals and radioactive substances may be targeted and thereby leak into surface waters and groundwater. During the recent war in the Balkans, NATO bombed petrochemical plants in the suburbs of Belgrade. Toxins such as chlorine and vinyl chloride monomer were released into the atmosphere.

Associated fuel combustion contributes to ozone depletion. The energy demands of military activities have been estimated at 6 % of the global total, which is more than that of many countries.

Combatants may plunder natural resources to finance military operations. Furthermore, combatants may deliberately or indiscriminately target the environment, seeking to deprive opposing troops of shelter, food, water and fuel. The oil slicks and burning oil wells of Kuwait demonstrated that natural fuel resources can also be caught up in armed conflict, with catastrophic impacts on the environment.

The aftermath
Discarded weapons, including chemical and biological, are potential sources of contamination and injury to plant and animal species, including humans. Military wastes have created major remediation challenges throughout the world. When Soviet troops withdrew from the former East Germany in 1992, 1.5 million tonnes of ammunition were destroyed, with the release of nitrogen oxides, highly toxic chemical dioxides and heavy metals to the atmosphere. Abandoned garrison towns around Berlin have hidden waste tips with millions of gallons of spent tank and truck oil, and chemical wastes, as well as ammunition. Officials have estimated that the 4 % of East German territory that was occupied by former Soviet bases and facilities is severely polluted.

In addition to the machinery of war, the movement, accommodation and wastes of millions of humans creates major impacts on natural systems. By far the majority are refugees displaced from their homes by military activities. As recent events have demonstrated, the tens of thousands of ethnic Albanian refugees pouring out of Kosovo into neighbouring countries quickly exceeded the capacity of those countries to support them. Food, water, sanitation and even land space were simply unavailable in some locations.

According to the International Committee of the Red Cross, landmines kill or maim between 1 000 and 2 000 people every month. A hundred million landmines now lie in wait around the world. Most victims are civilians in peacetime, with children being especially vulnerable.

Sources: Bruch, 2002; Heathcote, 2002; Eco-compass, 2002; The History Guy, 2001

the nuclear industry, and even minor incidents now accentuate the problem of diminishing public trust. Reports of increased numbers of leukaemia cases in areas surrounding some nuclear installations provoke great concern amongst the general public, in spite of independent investigations which conclude that there is no proof of a link between reports of higher doses of radiation in these areas and the incidence of leukaemia (European Commission, 1999).

By means of comparison, atmospheric nuclear testing of nuclear weapons resulted in the largest release of radionuclides into the environment and by far the largest collective dose from man-made sources, as shown in Table 10.3. By contrast, nuclear power production, nuclear weapons fabrication and radioisotope production result in comparatively small collective doses to the population. Accidents may have significant local impact, but only Chernobyl gave rise to a substantial population dose.

10.3.2. Radioactive waste management
Accidents and incidents involving the management of radioactive waste materials are not common occurrences. Between 1993 and February 1997, no incident or accident of radiological significance was observed in radioactive waste management operations. It

Figure 10.6. Number of operational nuclear power reactors in Europe (research reactors not included)

Source: IAEA, 2002a

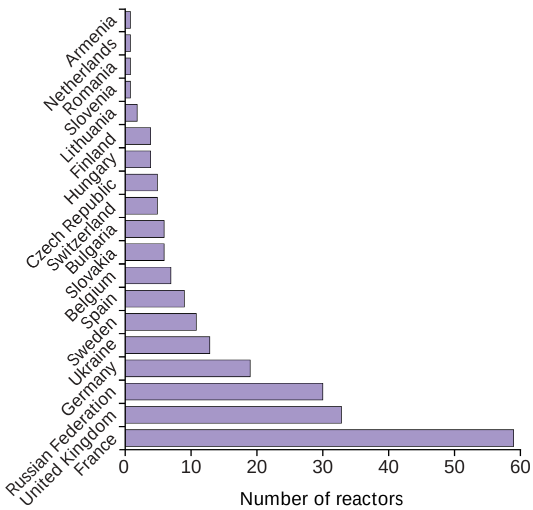


Figure 10.7. Age profile of operational nuclear reactors in Europe

Source: IAEA, 2002a

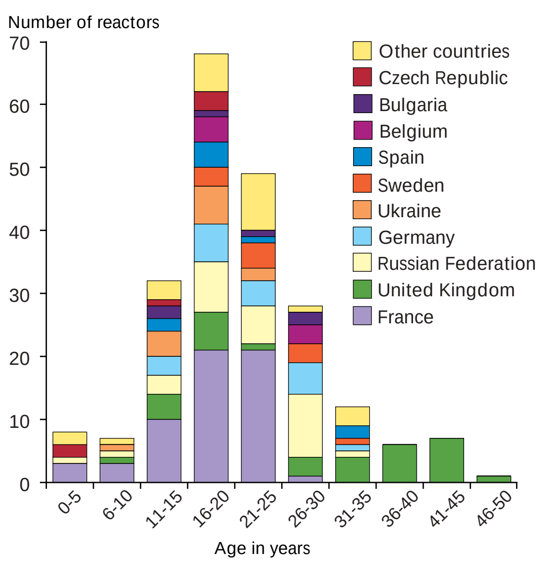
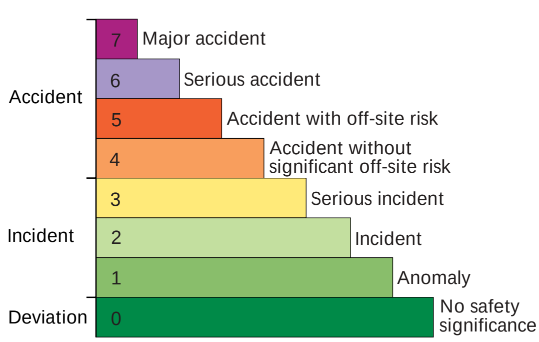


Figure 10.8. The international nuclear event scale

Source: IAEA, 2002b



is particularly noteworthy that in the area of transport of radioactive waste, which comes under close scrutiny by non-governmental organisations and the public, not a single entry is to be found in the INES (international nuclear event scale) database maintained by the International Atomic Energy Agency (IAEA) (Figure 10.8). The Chernobyl accident is so far the only nuclear accident to be assigned a 7 on the INES scale.

Fleets of nuclear power vessels also pose the problem of managing decommissioned material. Of the countries covered by this report which have fleets of nuclear powered vessels (France, the Russian Federation and the United Kingdom), the Russian Federation has built a massive 248 submarines, of which only 77 were in service in 1998 (NATO, 1998). Approximately 110 submarines have been taken out of operation in the Northern Fleet. It is anticipated that 18–20 submarines can be dismantled per year. As of beginning of 2002, 94 decommissioned nuclear submarines were stored afloat and have spent fuel in their nuclear reactors (Shishkin *et al.*, 2002).

10.3.3. Environmental and health effects of the Chernobyl accident

The explosion at the Chernobyl plant, Ukraine, exposed the reactor core and released radioactive fission and neutron activation products, including transuranics, from the reactor to the atmosphere. Most of refractory radionuclides in the form of hot fuel particles were deposited in the vicinity of the destroyed reactor. For some volatile radionuclides the release rate and transportation distance were exacerbated by heat from the fire that lasted 10 days. Estimated releases of the most radiologically important volatile radionuclides I-131, Cs-137 and Cs-134 were about 1 500, 85 and 46 PBq. The altitude which radioactive cloud reached (up to 3 km) and the prevailing winds meant that most of Europe was affected by the fallout. More than 140 000 km^2 of the territory of the three most affected countries, Ukraine, Belarus and the Russian Federation, and more than 45 000 km^2 of other European countries were contaminated with Cs-137 over 40 kBq/m^2 (see Map 10.1).

Several organisations have reported on the impacts of the Chernobyl accident, but all have had problems assessing the significance of their observations because of the lack of reliable public health information before

1986. In 1989 the World Health Organization (WHO) first raised concerns that local medical scientists had incorrectly attributed various biological and health effects to radiation exposure (UIC, 2001).

An IAEA study involving more than 200 experts from 22 countries published in 1991 was more substantial. In the absence of pre-1986 data it compared a control population with those exposed to radiation. Significant health disorders were evident in both control and exposed groups but, at that stage, none was radiation related.

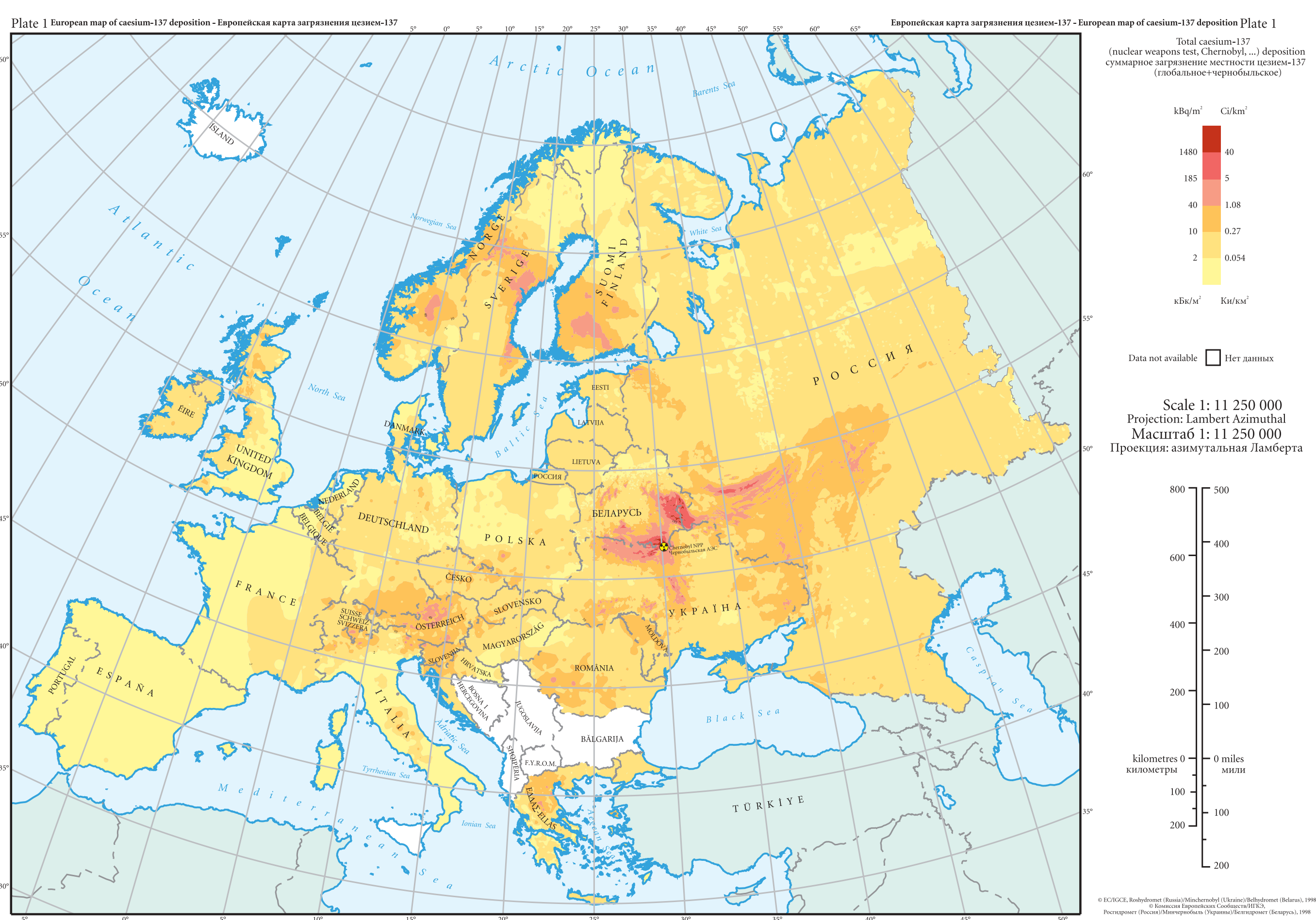
Subsequent studies in the Ukraine, the Russian Federation and Belarus were based on national registers of over 1 million people possibly affected by radiation. These confirmed a rising incidence of thyroid cancer among exposed children. Late in 1995, WHO linked nearly 700 cases of thyroid cancer among children and adolescents to the Chernobyl accident, and among these some 10 deaths are attributed to radiation (see Chapter 12, Section 12.2.4).

Doses from man-made sources Table 10.3.

Source	Collective effective dose (man Sievert)
Atmospheric nuclear testing	30 000 000
Chernobyl accident	600 000
Nuclear power production	400 000
Radioisotope production and use	80 000
Nuclear weapons fabrication	60 000
Kyshtym accident	2 500
Satellite re-entries	2 100
Windscale accident	2 000
Other accidents	300
Underground nuclear testing	200

Source: Bennett, 1995

Deposition from Chernobyl in Europe Map 10.1.



Source: European Commission, 1998

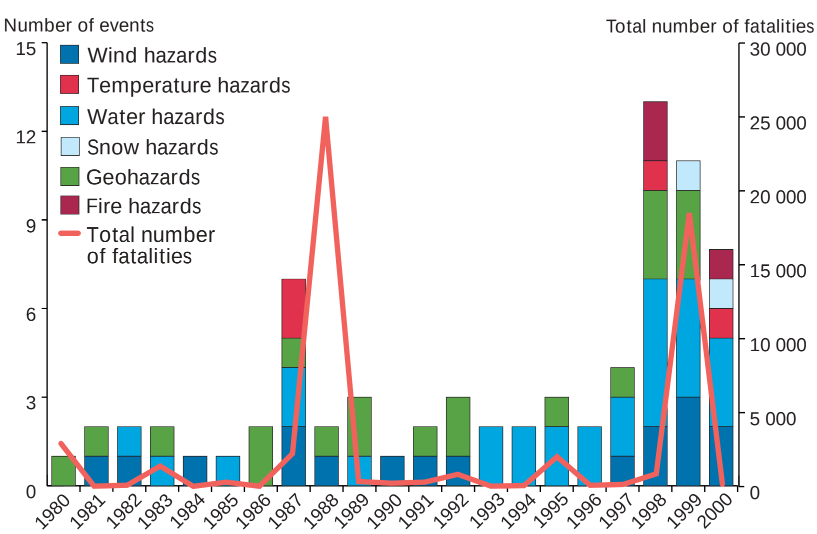
Despite the decay of most deposited radionuclides and applied countermeasures, a few tens of thousands of square kilometres in Belarus, the Russian Federation and the Ukraine will remain substantially contaminated with long-lived radionuclides, i.e. Cs-137, Sr-90, plutonium and Am-241 for decades. The levels of human external exposure and enhanced radionuclide concentrations in agricultural animal and natural food products (e.g. mushrooms, berries, lake fish and game) will also remain elevated over a long period (see also UN, 2002). These abnormal human exposure levels still require regular monitoring and, in some areas, remediation actions. Up to now approximately 100 000 inhabitants of contaminated areas receive additional annual doses above 1 mSv caused by the Chernobyl fallout (around 50 % less than the yearly dose from natural sources).

Psychosocial effects among those affected by the accident are emerging as a major problem, and are similar to those arising from other major disasters such as earthquakes, floods and fires.

10.4. Natural disasters

Natural disasters, such as earthquakes and landslides, are often more devastating, in terms of loss of life and environmental damage, than technological accidents, which they can also precipitate. The cost of natural disasters may run into billions of euros, rather than the millions associated with most technological accidents (with the exception of some worst cases such the Chernobyl accident). As with technological accidents, the consequences depend both on the magnitude of the event and factors such as population density, disaster-prevention measures and emergency planning.

Figure 10.9. **Events involving natural hazards and the associated number of fatalities in Europe, 1980–2000**



Source: Munich Re, 2001

10.4.1. Events associated with natural disasters

Figure 10.9 illustrates, for the whole of Europe, the number of events associated with natural disasters and the associated number of fatalities between 1980 and 2000. Several types of natural hazards are included and it is clear that they have the potential to cause large numbers of fatalities. The hazard that causes by far the largest numbers of fatalities in one event during this 20-year period is an earthquake. On 17 August 1999, a major earthquake in northwest Turkey, measuring 7.4 on the Richter scale, caused the deaths of more than 17 000 people, most of whom were crushed in the rubble of their collapsed homes. The earthquake also precipitated technological accidents, when fires broke out in oil refineries and explosions rocked the rubble as leaking gas ignited. On 7 December 1988, a massive earthquake rocked northwest Armenia, killing some 25 000 people (EQE Engineering, 1989). The recent earthquake at the southern Italian village of San Giuliano di Puglia on 31 October 2002 highlighted the traumatic effects caused by all fatal earthquakes. Of the 29 people killed, 26 were young children, buried after their school building collapsed (BBC, 2002c).

In Europe, as worldwide, storms and floods are the most common natural disaster and, in terms of economic and insured losses, the most costly, as illustrated in Table 10.4 (Swiss Re, 2002a).

Winter storms in Europe represent a major hazard to people and a major economic loss. Two of the worst storms hit Europe at the end of December 1999. On 26 December, Lothar crossed northern France, southern Germany and Switzerland within a few hours, leaving a path of destruction. The next day, Martin passed through further to the south, also causing heavy losses in central and southern France, northern Spain, Corsica and northern Italy (Swiss Re, 2002b).

The high speeds of both storms were attributable to unusually heavy westerly winds. Lothar attained its maximum intensity on the French Atlantic coast, maintaining its force far inland. Peak gust velocities reached

Most costly natural hazard insurance losses in Europe Table 10.4.

Date	Countries	Event	Victims	Insured loss (US$ billion, 2001 levels)
25 Jan 1990	Western Europe	Winter storm Daria	95	6.2
26 Dec 1999	Western Europe	Winter storm Lothar	80	6.2
15 Oct 1987	Western Europe	Storms and floods in Europe	22	4.7
25 Feb 1990	Western/ central Europe	Winter storm Vivian	64	4.3
27 Dec 1999	France, Spain, Switzerland	Winter storm Martin	45	2.6
3 Dec 1999	Western/ northern Europe	Winter storm Anatol	20	1.6

Source: Swiss Re, 2002a

170 km/hour in the heart of Paris and more than 180 km/hour at Orly airport, or 20 % above the maximum wind speed previously on record. Even before Lothar died out over eastern Europe, another powerful storm, Martin, reached the west coast of France at the latitude of La Rochelle. While Martin crossed the country about 200 km south of Lothar's track and registered weaker peak gusts, wind speeds of some 160 km/hour and 140 km/hour were registered in Vichy and Carcassonne, respectively.

Particularly in France, but also in southern Germany and Switzerland, losses triggered by Lothar and Martin were paralleled only by the storms of 1990. Casualties exceeded 80, not counting the lives claimed in the course of clean-up work. Some 44 of these fatalities occurred in France alone, while 17 were reported in Germany and 13 in Switzerland. The storms ravaged some 60 % of the roofs in the Paris region and damaged more than 80 % of the buildings in surrounding towns, some of them substantially.

Forests also sustained tremendous damage: in France, Germany and Switzerland, for example, the storms toppled several times the average annual timber yield. Power supply was also affected more seriously than ever before: in France alone, Lothar blew over more than 120 large power supply pylons (the combined total with Martin exceeded 200), leaving more than 3 million households without power for days.

Lothar and Martin generated economic losses of some USD 12 billion and USD 6 billion, respectively. Of these amounts, USD 6.2 billion (Lothar) and USD 2.6 billion (Martin) were insured. Overall, more than 3 million claims were filed with insurance companies in France, leading to claims settlements which exceeded the capacity of some insurers. These sums are in the top range of losses caused by winter storms in Europe to date and can be compared only with those triggered by the series of winter storms in 1990 (Swiss Re, 2002b).

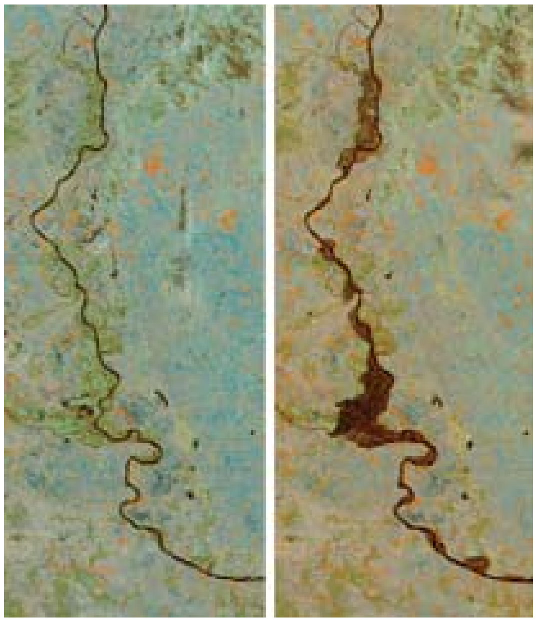
Flood damage depends on the duration and height of water levels, topography and use of the flood plain, flood defence measures, and the awareness of the population likely to be affected by flooding. The frequency of major flooding events in Europe has increased in recent years. As an example, at Kehl on the German-French border, between 1900 and 1977 the Rhine's floodwaters rose more than 7 m above flood level only four times. From 1977 to 1996, that level was reached 10 times, an average of once every other year (UWIN, 1996)

During the period 1978–2000, including natural variations, the level of the Caspian Sea rose by about 2.3 m. Flooding in coastal zones inundated residential areas, transport, telecommunications and energy infrastructure, chemical and petrochemical industries, croplands and hatcheries, forcing thousands of residents to be evacuated from flooded homes. In Turkmenistan, the town of Dervish, which is detached from the western part of the mainland, is turning into an island due to the rise in sea level (EIA, 2000).

In July 1997, floodwaters killed at least 52 people in Poland and 39 in the Czech Republic (ESA, 2001). A year later, again in

Figure 10.10. **Flooding along the Danube River, Hungary, Croatia, and Serbia and Montenegro in April 2002**

Source: NASA, 2002a



March 17, 2002 April 2, 2002

July, at least 46 died during flooding in the Slovak Republic, during a 'supercell storm'.

However, the catastrophic flooding in central Europe and the Black Sea region of the Russian Federation in August 2002 has surpassed these in terms of impact. At least 111 people died, with hundreds of thousands evacuated (BBC, 2002d). Many homes were completely destroyed. In Hungary, the River Danube broke high-water marks along 170 km of its length (Figure 10.10). The water reached a record of 8.49 m, breaking the previous record of 8.45 m set in 1965. In Dresden, Germany, the River Elbe reached 9.39 m, the highest since records began in the 16th century. Floods in Prague were the worst for 175 years. Economic losses have been estimated at more than EUR 15 billion (Swiss Re, 2002c).

Potentially dangerous acute and chronic impacts on industry were also apparent. A cloud of chlorine gas (several hundreds of kilograms) escaped from a flood-damaged chemical plant in Neratovice, about 20 km north of Prague. Considerably larger amounts (some 80 tonnes equivalent) were released into the water. Releases of some persistent organic substances could not be excluded. The impact of these releases is being evaluated. A dam burst near the town of Bitterfeld in southeast Germany, resulting in the evacuation of 16 000 people, and the emergency was heightened by the flooding of the adjacent chemical complex, where a military operation was launched to stop chemicals flowing into the River Mulde (BBC, 2002e). Most sewage plants along the Rivers Elbe and Vltava in the Czech Republic were put out of action, raising the prospect of environmental damage. The overall cost to industry and the general population is likely to run into many billions of euros.

Heavy rain and flooding can also precipitate landslides, which may be more catastrophic in terms of fatalities. In October 2000, Gondo, a Swiss alpine village, was 'sliced in two' by a fatal 40 m wide landslide, following three days of incessant rain (SAEFL, 2002).

Fatal avalanches have also hit alpine regions in recent years. In Europe, the winter of 1998/99 was one of the 'snowiest' in 50 years. Major snow storms created a number of avalanches in populated mountain areas across the Alps. Three separate incidents in February 1999 at Galtür (Austria), Evolene (Switzerland) and Chamonix (France) claimed the lives of 51 people (OFEFP, 2002).

10.4.2. Natural disasters exacerbated by human activities

From the available data (Figure 10.1 and Figure 10.6) it appears that the trend for the annual number of natural disasters is more obviously upward than that for major technological accidents. This is particularly apparent for those precipitated by human activities. For example, drainage of wetlands and straightening of rivers can influence both the probability and the magnitude of flooding, by increasing peak water flows. There is also an increased probability of occurrence of certain natural disasters, such as flooding and droughts, due to climate change, in many temperate regions (see Chapter 3). Climate change may be a contributor to the recent increase in flooding incidents.

Landslides are likely to increase unless there is better management of land to reduce soil erosion. Land clearing for agricultural reasons combined with the increased frequency of heavy storms and flooding will increase the risk. The landslide at Campania, Italy tragically illustrated this in May 1998 when, after two days of incessant rain, a torrent of mud engulfed hundreds of homes in the towns of Sarno and Quindici and surrounding villages. Almost 300 people were killed and about 2 000 made homeless. The clearing of trees and burning of scrubland to create pastures had led to massive erosion and in some areas chestnut trees had been replaced by hazelnut trees, which are much weaker and produce a smaller root system (EEA, 1999).

Land clearing by deliberately starting forest fires has led to direct hazard from the fire itself. Arson is a major cause of forest fires, although such fires have also occurred through natural processes. Forest fires, which occur every year across Europe, can cause fatalities and create vast clouds of smog over the surrounding area, in addition to the environmental disaster of the loss of extensive areas of forest. However, planned fires (if managed properly) clear away dead and dying vegetation to help rejuvenate forests and reduce the risk of larger, uncontrolled wildfires. Fire is also used to help clear forests for human developments. Around the world, every year, from 750 000 to 8.2 million square km of forest and grassland is burnt (NASA, 2002b).

10.5. Risk management

Disasters will continue to occur throughout Europe — some due to technology, some to the forces of nature, some to the combined effects of the two. Inevitably, there will be loss of life and environmental damage.

However, better management of hazards can reduce the risks. Although it is not possible to predict when disasters will occur it may be possible to identify the general areas where they are more likely, so that responses can be pre-planned and loss of life and environmental impacts minimised.

10.5.1. Technological hazards

For many technological hazards, holistic approaches are becoming more prevalent, with increasing attention to reducing the risks of long-term environmental impacts as well as acute health and property damage. For the process industries, the Seveso II directive in the EU requires industrial operators to demonstrate that they have taken all necessary measures to prevent major accidents and limit their consequences for humans and the environment.

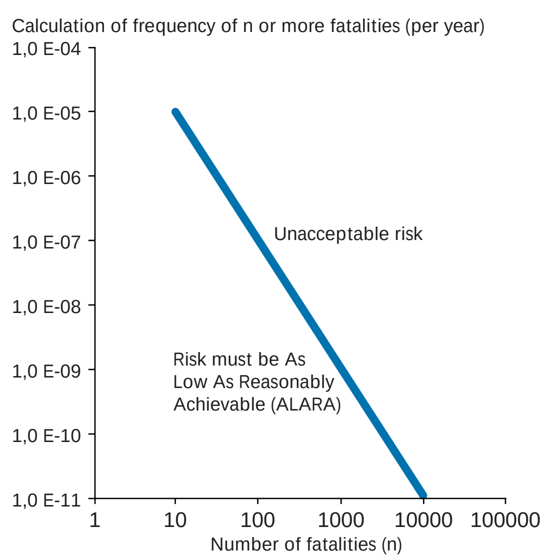
There is an improved culture with regard to reporting accidents and sharing the lessons learnt. Experience of accidents to cross-country pipelines and oil tankers has guided design, construction and operation, with a substantial reduction in incidents.

However, catastrophic events that are difficult to predict because of lack of specific experience are likely to remain a difficult problem. Although technological disasters account for only a fraction of the number of fatalities of natural disasters, there remains a perception that technological hazards pose a considerable risk, particularly to people living nearby. This is particularly true for nuclear hazards. There are many reasons for this, including lack of knowledge and dread, but also acceptability. An additional factor is a common aversion to technologies that could cause multiple fatalities. This is taken into account in the Dutch societal risk criteria where (for fatalities of 10 or more), a decrease in frequency of two orders of magnitude is required for an order of magnitude increase in fatalities (Figure 10.11).

Planners and policy-makers take such issues into account. Following the Toulouse accident, one of the points of the European Parliament Resolution of 3 October 2001 was that the current approach to 'risk management' had been overtaken by events and that it was now necessary and urgent to adopt an approach based on 'risk removal'.

Pre-planning for technological disasters is now common, through emergency response plans. In particular, since 1986, many countries and organisations in the EU have developed sophisticated computerised systems for gathering, managing, assessing and disseminating information about possible future nuclear accidents. For the

Dutch societal risk criteria Figure 10.11.



Source: VROM (the Netherlands Ministry of Housing, Spatial Planning and the Environment) process industries, the Seveso II directive has prescribed that onsite and offsite emergency plans must be in place and practised at regular intervals. EU countries are generally better prepared for technological disasters than those in eastern Europe.

Major transportation accidents pose a particular problem because it is difficult to predict their location. Many railways cross densely populated cities, and although the capacity of a standard tank car is limited to about 50 tonnes, this may be sufficient to cause a major catastrophe if a hazardous material is released in or close to an inner-city area. The consequences of a pipeline rupture could be severe, as a large amount of material could be released before isolation. With an ever-increasing pipeline network throughout eastern Europe and the Caspian region, there is an increasing likelihood of such events unless the risks are better managed.

For the non-EU states, the use of the Seveso II directive and other relevant directives, such as the water framework directive (Directive 2000/60/EU), appears appropriate and some are already using these, including some non-accession countries. The comprehensive nature of such directives, with their power to prohibit unacceptable activities, provides a valuable model for the more effective management of safety.

Increasingly, the management of technological risks must include the threat of international terrorism. The recent attack on the French oil tanker Limburg off the coast of Yemen on 6 October 2002 has highlighted this. There has been speculation that the Toulouse incident of 21 September 2002 was an act of sabotage. Whilst security of such sites has been increased over the last few decades, particularly those sites with nuclear installations, there are many softer targets at risk. Transportation routes are particularly vulnerable, and the example of oil pipelines attacks in Africa has demonstrated the potential for major accidents, disruption and environmental damage.

10.5.2. Natural hazards

For natural hazards, particularly earthquakes, the problem of predicting exactly when and where they may occur is a major difficulty for risk management. This is compounded by the fact that there are no means of preventing some natural events, such as earthquakes and volcanic eruptions, although for some events, mitigation measures that could be used are not adequately applied in land-use planning. The management of these hazards could benefit from the application of some of the control, mitigation and response approaches developed for technological hazards.

Adequate land management is essential. 'Inherent safety' is a term often used in the process industries to avoid the hazard in the first place. The corresponding approach would be to discourage settlement growth and reduce urban sprawl in areas that are susceptible to natural hazards. Where susceptible areas are populated, societal risk criteria, such as those shown in Figure 10.11 could be a useful tool in land-use management to limit settlement growth.

For regions under development, a holistic approach should ensure that all hazards are identified and that the risks from these are balanced against each other. The interactions between humans and the natural environment should be taken into account, as recent accidents have shown that this is an increasing causal mechanism. For example, while shrub clearing for agriculture may increase the likelihood and consequences of flooding, soil erosion and landslides in areas susceptible to heavy rainfall, it may help to prevent fires in susceptible areas.

For some natural hazards, some control measures may prevent the full potential of the hazard from being realised, even if they cannot prevent it. For example, the catastrophic effects of an avalanche can be reduced by initiating controlled avalanches to avoid a large build-up of unstable snow. Flood warning systems may provide sufficient time to remove people from the source of danger. For a number of years, the Thames Barrier has protected London from flooding due to a high tide. The huge cost of an accident, including that associated with loss of life and injury, generally far outweighs the cost of such risk reduction measures. Increasingly, in seismically active regions, new buildings, chemical plants and pipelines are designed to withstand the stresses of earth movement. Shoddily built housing was the main factor cited for the high death toll in the 1999 Turkey earthquake.

Some EU Member States have procedures in place for taking account of the risks of flooding, avalanches, landslides and earthquakes in their planning and development processes. However, these procedures have resulted in haphazard responses to natural disasters and, in many cases, the impacts on humans, the environment and the local economy have not been mitigated. According to experts, poor planning, fragmented warning and defence systems, and deforestation may have all worsened the consequences of the flooding in central Europe during 2002 (BBC, 2002f). The 1999 Turkey earthquake is a tragic reminder of how a lack of comprehensive disaster management can increase the consequences. In the weeks after the earthquake, health workers battled to prevent the spread of typhoid fever, cholera and dysentery. According to the International Red Cross, even one year after the disaster, the survivors were the victims of psychological trauma and physical deprivation (CNN, 2000). Even 10 years after the 1988 Armenia earthquake, some 350 families were still waiting for homes to be constructed for them and were living in containers, wagons or shacks (Naegele, 1998).

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