3.8. Natural and technological hazards

Main findings

Since the late 1980s, natural hazards have had a bigger impact on the environment. Furthermore, between 1990 and 1996, economic losses due to floods and landslides were four times those in the whole of the preceding decade.

In spite of measures on major industrial accidents in force since 1984, the trend in accidents shows that many of the often seemingly trivial 'lessons learned' from accidents have not yet been sufficiently evaluated and/or implemented in industry's practices and standards. On the other hand, the risk of major accidents per unit of activity seems to show a slight downward trend.

In contrast to industrial accidents in fixed installations, major oil spills due to marine transport accidents as well as offshore installation accidents have shown a clear downward trend.

Lack of sufficiently detailed, comparable information on the risks posed by certain types of nuclear facilities, including the treatment of waste, means that the overall risk to the European environment from accidental releases of radionuclides, even if small, cannot be quantified. However, a gradual improvement in the overall risk of accidents is expected. A complicating factor is the increasing deterioration of the older plants in Eastern Europe.

Sound information on current natural and technological hazards is essential. Important questions include: Which hazards are connected with chronic changes to the environment, such as global warming and sea-level rise? Are human activities increasing the risk from various hazards?

1. Accidents still happen

Accidents, whether natural or technological, continue to occur throughout the EU and in the Accession Countries and lead to environmental damage and the premature deaths of people. In 1997, there were a total of 37 major industrial hazard accidents reported in the EU, the highest annual number since records began. The number of major floods in the EU also increased during the 1990s. Although major hazards are less frequent than, say, traffic accidents, they are of great concern as sources of impacts on the environment and human health. This concern arises mainly from their unpredictability in terms of where and when they will happen and the scale of the impacts.

1.1. We are all living with risk

There is no such thing as 'zero risk' to individuals, society or the environment. No matter how people occupy their time, whether at home or in a hazardous industry, they are exposed to a number of hazards and risks. In a wide variety of industries, many of which have benefited from many years of design evolution and operational experience, there remains a residual risk which must be consciously managed and controlled. Moreover, in many areas, people are living with a relatively high level of risk from natural hazards, such as earthquakes and flooding.

Clear factual information is required for the public and policy-makers to assist in recognising the problems associated with this risk and to help in the improvement of accident prevention and disaster response. This includes information about 'reasonable doubt' concerning hazards or risks, or lack of information in areas of concern. The public perception of various hazards and risks, and the influence of various pressure groups, can be a major factor, but the perceived risk is often far removed from reality. For example, the number of fatalities from natural hazards far outweighs those from major industrial hazards (95% of the total in the period 1985-96) which may be contrary to public perception.

1.2. Policies have been implemented…

The 5th Environmental Action Plan has targeted certain sectors to set out an integrated policy-cum-strategy for both environmental themes and causes of environmental degradation. These sectors include industry (petrochemicals, chemical, manufacturing, water, etc.), energy (oil and gas, nuclear, etc.), transport (dangerous goods by road, rail, ship) and military.

The most significant EU Directive to help protect people and the environment from major accident hazards is the Seveso II Directive (Box 3.8.1). This Directive applies to those industries that use significant amounts of materials that are hazardous to people and the environment. Operators must demonstrate that they have a policy for the prevention of major accidents (safety management systems), that they have assessed the risks and are managing these, and that they have adequate response plans in case of emergencies.

Previous policies and associated regulations on major hazards have focused on the acute effects, mainly on human health. However, there is a particular lack of information on the long-term effects of accidents on the environment. This is often due to the paucity of baseline information available. It is virtually impossible to assess the long-term ecological damage from a spill of toxic chemicals into a river if the original state of the ecosystem had not been previously examined. Hence the need for Directives such as the proposal to establish a framework for Community action in the field of water policy (European Community, 1997b).

Box 3.8.1 General aims of Seveso II Directive

to limit major accidents which involve hazardous substances

to limit the consequences of major accidents to humans and the environment

to ensure high levels of protection throughout the European Community in a consistent and effective manner

Source: European Community, 1997a

1.3. … but some hazard types call for special attention

1.3.1. Radiation accidents

The risk from an accidental release of radioactivity from a nuclear installation is a special type of hazard arising from technology to which much attention has been given by policy makers and the public. A large radioactive release has the potential to cause irreversible and far-reaching effects, as was seen by the accident at the Chernobyl nuclear power station in the Ukraine in 1986 which had huge health, social and environmental consequences. Accidental releases of gaseous or liquid toxic materials into the environment are not subject to direct limitation of the amounts involved and the probability of such releases in either the nuclear or non-nuclear fields. However, the competent national authorities do carry out safety analyses of nuclear installations prior to licensing and have in many cases developed national criteria for the consequences of an accident occurring as a function of the potential population exposure.

Thus, different countries have their own national approaches for acceptable levels of dose and risk. There is no unifying legislation but due to the work of ICRP, UNSCEAR and others, there is a widely accepted philosophy of radiation protection and unifying recommendations by international scientific organisations, which find their way into national legislation. There is also a move towards integrating radiation safety issues into the broader context of environmental safety. The perception of risk, however, is not uniform and different countries express their standards of safety in different ways. The European Commission has formulated Basic Safety Standards (BSS) for radiological protection, which form part of EU legislation (European Commission, 1996a). The fundamental limit on whole body exposure for members of the public in the EU BSS is 1 mSv per year. Probability criteria for risk of death from an accidental release from a nuclear installation have been set by a number of countries in Europe, at levels ranging from 10^{-5} per year (United Kingdom) to 10^{-6} per year (the Netherlands). A number of European countries have also set limits on the probability of occurrence of large releases of radionuclides.

1.3.2. Natural hazards also to be addressed

Certain environmental hazards have not been addressed by previous environmental policies. For example, the recent environmental disaster in the Guadiamar valley in Spain, where toxic mud burst from a mine reservoir and cascaded down the valley, impacting the Doñana National Park, Spain's most important nature reservoir (the Chemical Engineer, 1998), is not addressed by the Seveso II Directive, although the environmental effects were catastrophic. There is a need to identify such major hazards that are not immediately obvious to policy makers or engineers.

There is no targeted policy to reduce natural hazards, although programmes such as EPOCH (the European Programme On Climatology and natural Hazards) have specifically addressed this source of risk. The relative importance of natural hazards must be addressed to determine the significance of these in environmental concerns, particularly as such hazards have the potential to cause several hundred or even several thousand fatalities in one incident. Human impacts can to some extent be prevented by integrated land-use planning, although the spreading of settlements has seen a progression into higher risk areas, for example from flooding, where the risk appears to be increasing, possibly with the onset of climate change. Emergency response plans have been produced throughout the EU to react to various natural disasters, but these appear to be ad hoc, generally not tested, and are considered unlikely to work well in practice.

2. Are we having more major accidents?

The available evidence shows that whilst there has been a reduction in accidents in some areas, others have actually seen an increase during the past decade.

2.1. Industrial accidents

2.1.1. Trend slightly increasing

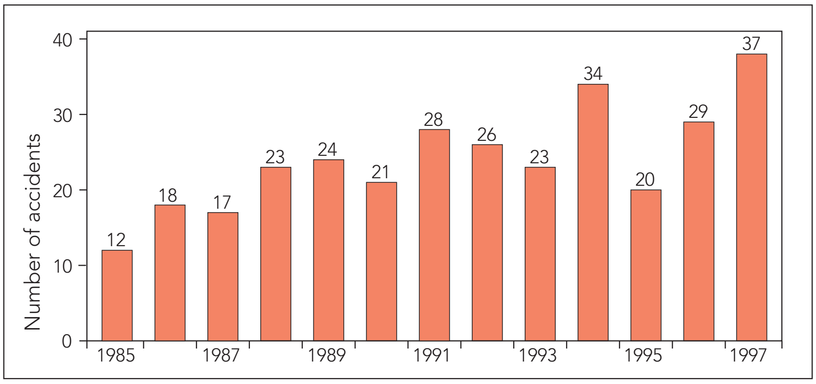
In the EU, the number of major industrial accidents reported every year has shown a slight upward trend since 1984, the year when the Seveso Directive (European Commission, 1992) was introduced (Figure 3.8.1). For the period 1984 to 1999, over 300 accidents have been reported by the EU Member States to the European Commission's Major Accident Reporting System (MARS). Since the rate of reporting major accidents to MARS is in good correspondence to the actual rate of occurrence of major accidents, this gives an indication that many of the often seemingly trivial 'lessons learned' from accidents have not yet been sufficiently evaluated and/or implemented in industry's practices and standards. Therefore, many efforts are still necessary to further reduce the risks related to major accidents from fixed industrial installations. On the other hand, since the industrial activities which give rise to most of the major accident risks are increasing in intensity in Europe, the risks of major accidents per unit of activity seem to have a slightly falling tendency.

However, lessons learnt are soon forgotten. One of the foremost authorities on safety, Trevor Kletz, writes that organisations have little memory when it comes to safety (Kletz, 1993). Industrial accidents for the most part are not new occurrences – their root causes can often be the same as previous accidents which did not involve significant damage or injury to workers or bystanders. In many cases, companies investigate only the immediate causes, such as operator error or the misuse of substances, and thus the root cause, such as inadequate engineering or management failures, remain unaddressed.

Information for industrial sites from the MARS database indicates that major accidents involving hazardous substances usually result from a number of simultaneous causes, such as operator error, component failure, and uncontrolled chemical reactions. Recent detailed analyses of major accidents (Drogaris, 1993; Rasmussen 1996) indicate that component failure and operator error were the two most common immediate causes of major accidents, but the dominant underlying causes identified (for 67% of the accidents) were due to poor safety and environmental management, resulting in a lack of control. Lack of expenditure on safety and environmental aspects is often a result of pressure from shareholders to increase profitability, although this may result in major losses in the long run.

The age of process plant is a major factor in the likelihood of accidents, as the probability

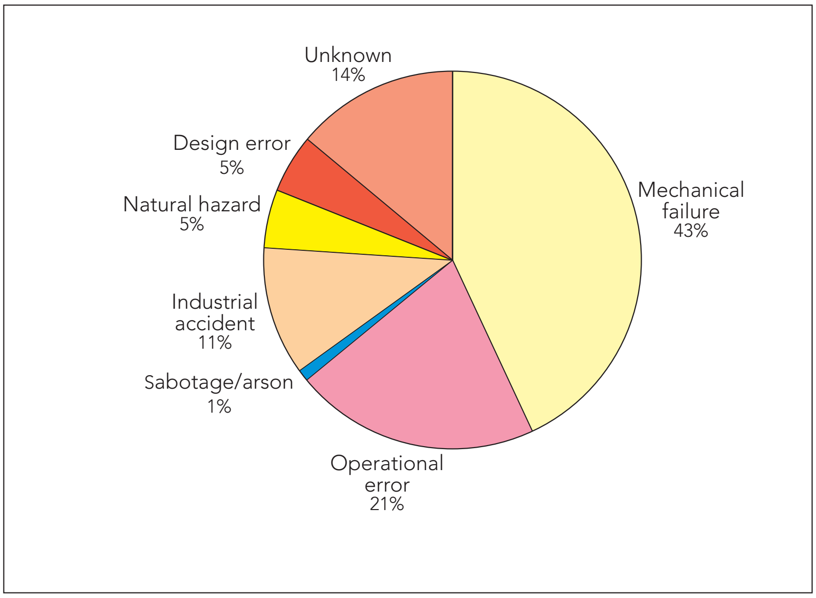
Number of major accidents in the EU reported to the MARS database, 1985-1997 — Figure 3.8.1



Source: MARS database

of 'wear-out' failures increases with age. The most frequent cause of accidental releases in the hydrocarbon-chemical industries cited by M&M Protection Consultants (1997) is 'mechanical failure', as shown in Figure 3.8.2, and a significant proportion of these are due to 'wear-out', which highlights failures in preventative maintenance programs. Many plants are operated past their design life in an attempt to gain the maximum return on investment and, as such, accidents are more likely.

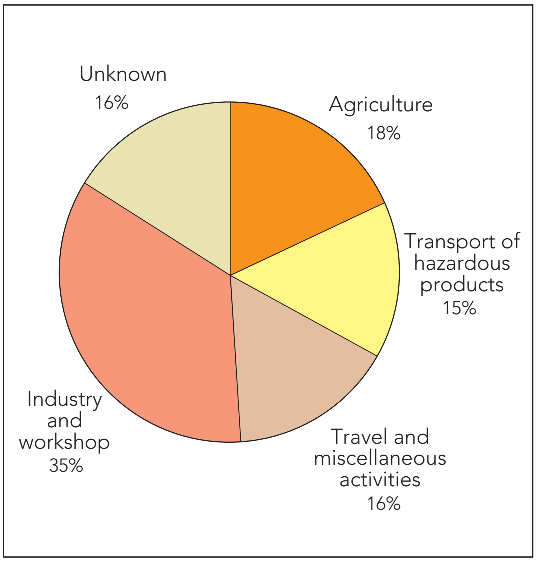
Figure 3.8.2 **Causes of accidental releases in the hydrocarbon-chemical industries**



Source: M&M Protection Consultants, 1997

Figure 3.8.3 **Number of technological accidents in France in 1997**

Source: BARPI database



2.1.2. Accidents occur in a variety of industries
Many people associate the chemicals industry with major technological hazards and indeed the majority of sites that are subject to the Seveso Directive would be described as chemicals facilities. However, there are many other sectors where serious accidents occur, resulting in fatalities and major injuries, although there may not be the same potential for off-site effects. In France in 1997, there were four sectors with a worse accident record than the chemical industry, as shown in Figure 3.8.3.

Arguably, hydrocarbon accidents and oil spills at sea gain the most media attention. The Piper Alpha explosion in the North Sea in 1988 caused 167 fatalities (Cullen, 1990). The most recent oil spill in the EU was that of the Sea Empress near Milford Haven, UK, where 72 000 tonnes of crude oil impacted 200 km of coastline (MIAB, 1997). The environmental impact of oil spills can vary considerably. This depends less on the quantity of oil spilt than the type of oil, prevailing weather conditions and whether or not the oil is spilt in coastal waters which are ecologically sensitive. Furthermore, without overlooking the unacceptable short- or medium-term impacts of oil spills, it is worth noting that in the long term devastated areas can recover. Thus for example, the impacts caused by one of the largest spills ever, from the Amoco Cadiz 300 km off the Brittany coastline in 1978, were only felt in the immediate years following (Bonnieux *et al.*, 1993) and the area is now thriving again. Currently, there is little evidence of irreversible damage to marine sources, either from major oil spills or from chronic sources of oil pollution. However, there has been little long-term monitoring of the biological effects of oil on the various forms of marine life. More extensive monitoring and research will be required before the potential chronic effects of oil spills are known (ITOPF, 1998).

2.1.3. Community life often disrupted as a consequence
The consequences of major industrial accidents in the EU are listed in Table 3.8.1. About 16% of these accidents resulted in loss of life and about one-third included fatalities in neighboring communities. About two-thirds of the accidents resulting in ecological harm involved water pollution (reservoirs, rivers) and in about half of these the pollution was caused by firewater runoff. However, it is difficult to gauge the long-term effects of such accidents and there is insufficient data.

2.2. Natural hazards are the most devastating

2.2.1. What are they?
Natural hazards, such as earthquakes and landslides, are often more devastating, in terms of loss of life and environmental damage, and also have the potential to precipitate technological hazards. As with technological accidents, the consequences depend both on the magnitude of the event and on factors such as population density, disaster-prevention measures and emergency planning.

Figure 3.8.4 illustrates, for the whole of Europe, the number of incidents associated with natural hazards and the associated number of fatalities between 1980 and 1996. Several types of natural hazard are described and it is apparent that they have the potential to cause large numbers of fatalities. The available evidence suggests that the hazards that cause the largest numbers of fatalities in one event are earthquakes (Box 3.8.2). In the 1990s there have already been 13 earthquakes world-wide where the fatalities have exceeded 1 000 people. Next to earthquakes, landslides and flooding have the potential to cause the largest numbers of fatalities in one event.

2.2.2. Human influence causes the increase
The trend for the annual number of natural-hazard accidents is more obviously upward than that for major industrial accidents. This is particularly clear for those precipitated by human activities, such as land clearing (see Chapter 2.3); other types of natural hazard, such as earthquakes and volcanoes, do not show any increasing or decreasing trends.

Consequences of industrial accidents in the UN notified to MARS since 1984 — Table 3.8.1.

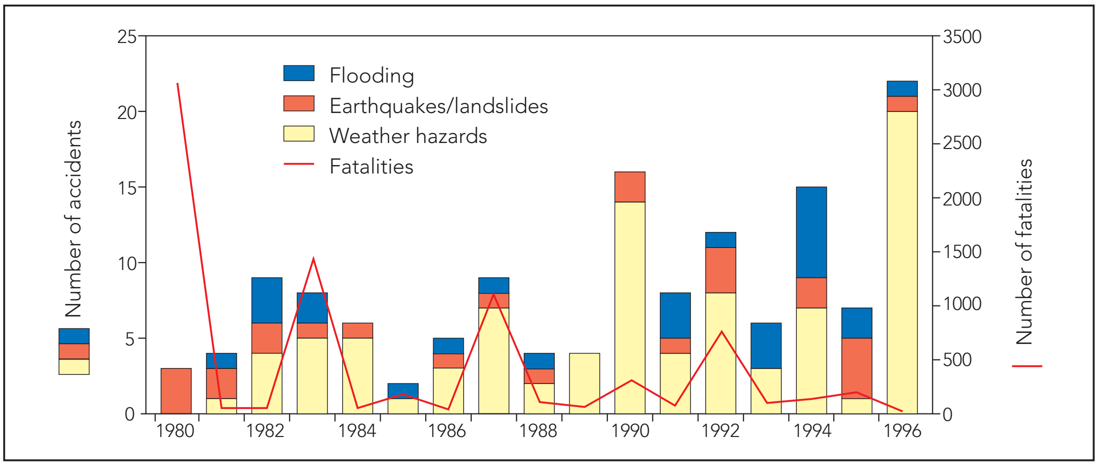
Consequences		Number of Accidents[1]
None or negligible		43
Fatalities	- on site[2]	47
	- of site	16
Injuries[3]	- on site	94
	- of site	26
Ecological harm		21
National heritage loss		0
Material loss[4]	- on site	57
	- of site	9
Disruption of comunity life		121

1 Each accident can have multible consequences, hence the total exceeds the total number of accident reported in the period.
2 Fatalities and injuries on-site are those to internal staff, contractors and emergency teams at or near the site of the accident.
3 Injuries include minor injuries as well as those requiring 24 hours or more of hospitalisation.
4 Material losses refer to cases where credible cost estimates have been given.

Source: MARS database.

Since the late 1980s, there has also been an apparent increase in the impacts of natural hazards (Swiss Re, 1993). As an example, at one city on the German-French border (Kehl), between 1900 and 1977 the Rhine's floodwaters rose over seven metres above flood level only four times, or about once every 20 years. Since 1977, that level has been reached 10 times, an average of once every other year (UWIN, 1996). This leads to a multitude of economic losses. Data from

Accidents involving natural hazards and the associated number of fatalities in Europe 1980-1996 — Figure 3.8.4



Note: exact figures for numbers of fatalities only for 1980, 1982, 1983, 1987, 1991. Where no exact number is available, a smallest estimate has been used.

Source: OECD Environmental Data, 1997

Box 3.8.2 Seismic activity in the EU

Earthquakes are widespread in the EU (Wild, 1998). The most destructive events have occurred in the Mediterranean countries, particularly Greece and Italy, which are in the collision zone between the Eurasian and African crustal plates, as shown in Figure 3.8.5. Smaller earthquakes are felt by other nations, although there is generally little damage.

The European Mediterranean Seismological Centre (EMSC) co-ordinates rapid acquisition and dissemination of information on earthquakes greater than 5.5 on the Richter scale. A major earthquake is defined as having a magnitude of 7 or greater on the Richter scale (USGS 1998a).

Examples of earthquakes in the EU in the past 25 years resulting in severe impact are as follows

1976	Greece, Thessaloniki	45 dead, 220 injured, major damage
1976	Italy, Frioul (twice)	977 dead, 2 400 injured, 189 000 homeless
1979	Italy, Umbria	5 dead, numerous injured, 2 000 homeless
1980	Italy, Campania	2 739 dead, 8 816 injured, 334 000 homeless
1980	Portugal, Azores	50 dead, 86 injured, 21 296 homeless
1981	Greece, south regions	19 dead, 500 injured, 12 220 buildings damaged/destroyed
1983	Belgium	1 dead, 26 injured
1984	Italy, central regions	7 500 homeless
1986	Greece, Kalamata	20 dead, 300 injured, 2 000 buildings damaged/destroyed
1990	Italy, SW Sicily	12 dead, 99 injured, 14 596 homeless
1992	Netherlands, Limburg	Extensive damage

Source: European Commission, 1996b

Effects on people and the environment
The list of earthquakes gives evidence of the potential catastrophic effects that an earthquake can have on society. However, the effects will continue long afterwards. There may be secondary effects such as flooding, landslides and fires, or even the precipitation of major technological disasters. Numerous people will need to be rehoused, either due to the destruction of their homes or out of fear of a recurrence, although people generally remain in the area (European Commission, 1996b). The event (and its anticipation for those in high risk areas) may cause severe trauma and this will be amplified by factors such as decomposing bodies which have not been cleared away, polluted drinking water and lack of essential supplies, particularly if the earthquake has affected transport.

Civil protection
Each EU member state has a programme for Civil Protection. In Greece, where there is a higher risk of major earthquakes, the Earthquake Planning and Protection Organisation (EPPO) is responsible for planning national policy regarding seismic prevention, education-information and protection (European Commission, 1996b. EPPO has established an emergency scientific team of various experts to advise the government body that co-ordinates action plans in case of disasters.
The EMSC has co-ordinated a two-year project to extend data communications and acquisitions to allow the rapid release of information for any earthquake of a magnitude greater than 5.0 occurring in the European-Mediterranean region (Wild, 1998). This information is issued in a two-step procedure, with the location, depth, time and magnitude of the earthquake generally available within one hour, followed later by detailed information on the earthquake's source mechanism. Such forward planning and the rapid dissemination of information will help in the protection of the public in these high risk regions, although such is the nature of earthquakes that there will always be casualties from major incidents. Unfortunately, city planning policies and building codes invariably have been insufficiently mature to ensure that structures are constructed in a manner that mitigates earthquake damage and affords civil protection (Gunn, 1998).

Munich Re (1997) reveal that in Europe in the seven-year period 1990-96, economic losses due to floods and landslides were four times the loss in the complete 1980-89 decade.

Landslides, one of the major causes of fatalities, are likely to increase unless there is adequate management of the land to reduce the likelihood of soil erosion. There is also an increased likelihood of certain natural hazards, such as flooding and droughts, due to climate change, in many temperate and humid regions (see Chapter 3.1). Furthermore, susceptibility to these hazards may be enhanced by certain land-use activities, and the lack of environmental management in land-use planning (see Box 3.8.3 and Chapters 3.12-15).

In Europe, as world-wide, storms and floods are the most common natural disaster and, in terms of economic and insured losses, the most costly. The damage caused by floods

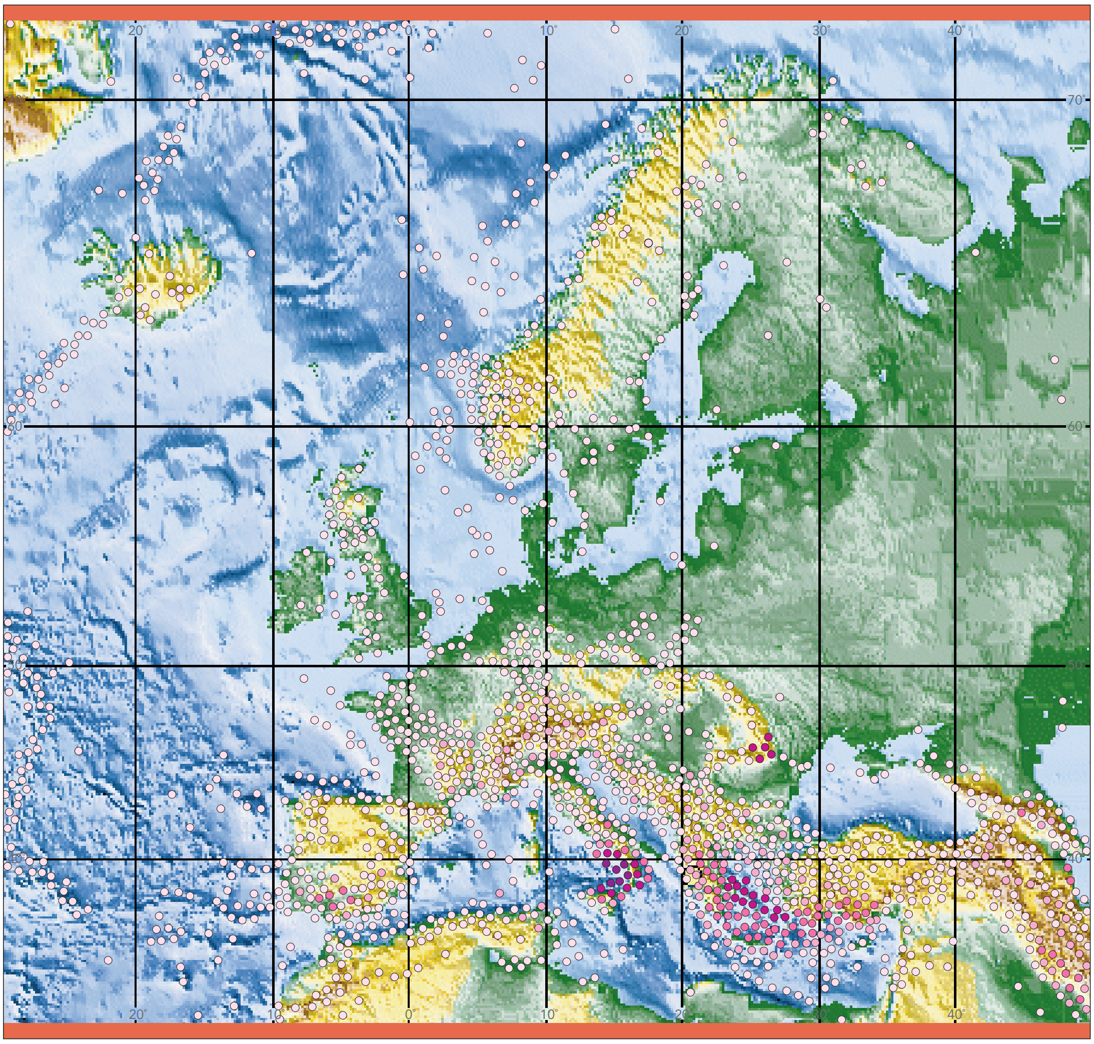
Box 3.8.3 The Campania landslide of 5 May 1998

What happened?
After two days of incessant rain, torrents of mud and water engulfed hundreds of homes in the southern Italian region of Campania, killing almost 300 people and leaving around 2 000 homeless. The area affected was a 50 km strip between the cities of Naples and Salerno. The landslide moved through the towns of Sarno and Quindici and surrounding villages, tearing apart houses and bridges, submerging cars and causing severe panic among residents, some of which sought escape on roofs. The mud then dried and solidified in intense sunshine, trapping persons caught in it. There was little preparation for the tragedy, although during the past 70 years 631 landslides have hit the region and about 3 800 people in Italy have been killed from mudslides since 1945. Subsequently, there was a lack of co-ordination between various response groups. Funds of about EUR30 million were later earmarked to aid initial relief and reconstruction.

Underlying causes
The landslide was caused by heavy rain over two days, although the 150 mm in total fell far short of any records. The consequences were intensified by human changes to the surroundings. The clearing of trees and burning scrub-land to create pastures or make room for construction led to massive erosion in the Campania region. In some areas, chestnut trees were replaced with hazelnut tress, which are much weaker and produce a smaller root system. Houses had been built without permission in areas where construction is forbidden because the land is geologically unstable. The Sarno river has diminished, the water being used by industry and the river bed had been built upon. Thus, there was no natural path for flood waters to escape.

The need for improved land management
The disaster revealed several shortcomings in land management and disaster prevention and response. For the past half-century geologists have warned against the construction of housing in the area, due to the high risk of mudslides. This risk was increased by removing vegetation from the mountains and interfering with natural water channels. Improved land management is essential to reduce the risk of further landslides. Training exercises for disaster response would facilitate improved co-ordination between the various response groups and the lessons learnt from this and other disasters need to be widely disseminated.

Sources: Hanley, 1998; CNN, 1998; Ieropoli, 1998



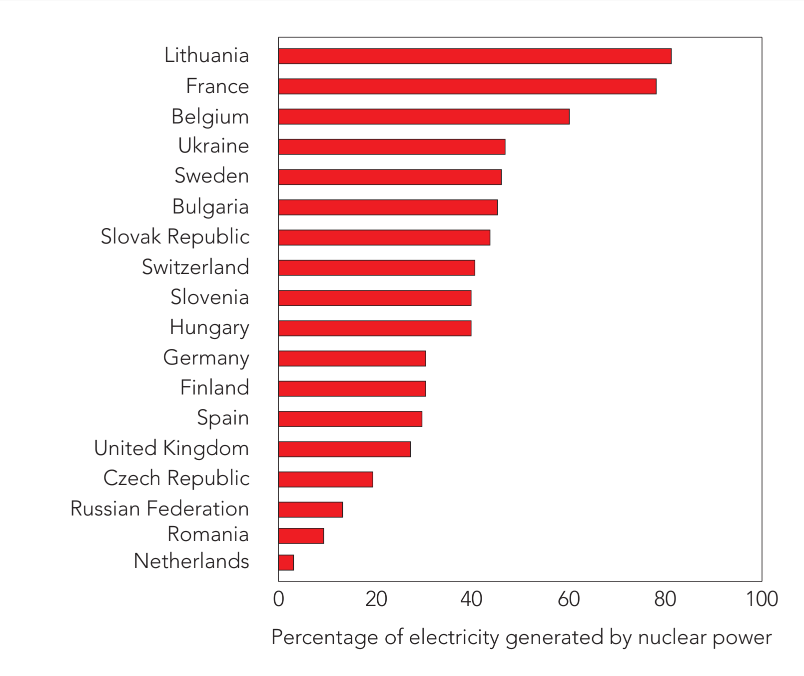
Seismicity of Europe

Depth in km
- 301 – 800
- 151 – 301
- 71 – 151
- 33 – 71
- 0 – 33

Figure 3.8.5

Source: USGS National Earthquake Information Center, 1998b

Figure 3.8.6 **The percentage of energy produced by nuclear generation in European countries that utilise nuclear power.**



Source: ??

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. However, human activities can influence both the likelihood and magnitude of the flooding, for example drainage of wetlands and straightening of rivers increase peak water flows. Also, in mountainous areas the clearing of land for agricultural purposes or developments, including those related to heavy tourism, may lead to soil erosion and landslides. Land clearing has been conducted by deliberately starting forest fires, although in many regions fires have occurred by natural processes. Forest fires, which occur every year in the EU, can not only cause fatalities, but can create vast clouds of smog over the surrounding area, as well as the environmental disaster of the loss of extensive areas of forest.

2.3. Nuclear accident risk declined lately

2.3.1. Nuclear power production facilities are the focus

Generating electricity from nuclear power is a well-established technology, with more than 30 countries world-wide operating or building plants. Nuclear generation today accounts for about 17% of the electricity produced globally and about 34% in the EU. While a number of European countries use nuclear power extensively and are likely to continue to do so (Figure 3.8.6), it is unclear to what extent nuclear power will be used to meet the projected increases in demand for electricity. The prospects for the extended use of nuclear power globally have recently been reviewed by the International Atomic Energy Agency (IAEA, 1996c).

Nuclear reactors generating electricity are not the only plants in Europe (Table 3.8.2) which have the potential to cause accidental releases of radionuclides. Other types of plant include nuclear reprocessing plants, other nuclear fuel-cycle facilities, plants producing pharmaceutical products and medical sources, and nuclear weapons development plants. Plants of all these types exist in Europe; for example the numbers of fuel-cycle facilities in Europe are shown in Table 3.8.3. In addition to accidents occurring at nuclear installations, accidental damage to radiation sources used in medical or industrial applications may also result in releases of radionuclides. There is also the potential for accidents in nuclear-powered submarines.

2.3.2. Radiation exposure risk assessment, a model to follow

Apart from the Chernobyl accident in 1986 other accidents have occurred in Europe over the past 40 years. Some of these have had environmental consequences, although these have been minor compared with the effects of Chernobyl. These other accidents include the 1957 Windscale fire in the UK and the nuclear weapons accident at Palomares in Spain in 1966. Environmental contamination from these accidents was localised, and the collective radiation doses were low. There is little or no remaining contamination in Western and Central Europe now from accidental sources other than from Chernobyl.

Atmospheric testing of nuclear weapons resulted in the largest release of radionuclides into the environment and by far the largest collective effective dose from man-made sources (Table 3.8.4). By contrast, nuclear power production, nuclear weapons fabrication and radioisotope production result in comparatively small doses to the population. Accidents may have significant local impact, but only Chernobyl gave rise to a substantial population dose.

Much information is available on the current levels of radioactivity in the environment in Europe. This is published nationally, and is also collated by the European Commission which periodically issues a compilation of levels of environmental radioactivity in the EU, on the basis of reports from Member States. The most recent of these covers the year 1993 (European Commission, 1998).

The assessment of risks from radiation exposure has led the field of environmental risk assessment for many years and has been the model followed for other sources of contamination. Therefore many aspects of the assessment from nuclear installations are significantly more developed than those in other fields. In particular, techniques for assessing the potential accidental risk posed by nuclear installations are well developed (London, 1995). However, the availability of the results of such studies varies.

Assessments of risks posed by the newer designs of nuclear power stations are comprehensive, and have in some cases been published (Kelly and Clarke, 1982). Less and in some cases no information is available for other types of plants. For example, there is no published comprehensive summary of the risk of accidents from Europe's reprocessing plants. Accident risk information for Europe's nuclear installations has not been collated internationally although much information exists at a national level. Moreover, the use of different approaches at national level (as already noted) would render any uniform collation extremely difficult to prepare. It is not known, therefore, to what extent existing national risk assessments might be judged internationally to be sufficiently comprehensive as regards the range of accidents scenarios and types of plant taken into account.

The older types of reactors found on a number of sites in Eastern Europe present a greater hazard than the more modern Western designs. This includes the RBMK reactors, found in Russia, Ukraine and Lithuania, including the Chernobyl plants, and the first generation pressurised water reactors (VVERs), located in Bulgaria and Slovakia. These are considered to have some of the most serious design deficiencies (IAEA, 1996d). It is also possible that accidents occurring at plants outside Europe could present an environmental threat to countries in Europe – Chernobyl demonstrated the great distances potentially affected – but again information on the risk posed by plants outside Europe has not been collated. The risk from potential accidents involving medical and industrial radiation sources has also not been collated.

Status of nuclear power reactors in Europe (1995) Table 3.8.2.

Country	In operation	Under construction	Shut down	Suspended	Cancelled
EU Member States					
Austria					1
Belgium	7				
Denmark					
Finland	4				
France	56	4	10		
Germany	20		16		6
Greece					
Ireland					
Italy			4	3	
Luxembourg					
Netherlands	2				
Portugal					
Spain	9		1		4
Sweden	12		1		
United Kingdom	35		10		
EU total	**145**	**4**	**42**	**3**	**11**
Central & eastern European Accession countries					
Bulgaria	6				1
Czech Republic	4	2			2
Hungary	4				
Lithuania	2				1
Poland					2
Romania		2		3	
Slovak Republic	4	4	1		
Slovenia	1				
CEE Accession countries total	**21**	**8**	**1**	**3**	**6**
Other countries					
Switzerland	5				
Armenia	1				
Russian Federation	29	4	4	6	10
Ukraine	16	5	1		3
Total other countries	**51**	**9**	**5**	**6**	**13**
Total Europe	**217**	**21**	**48**	**12**	**30**

Source: IAEA, 1996a.

Table 3.8.3. Number of fuel cycle facilities

Country	Mining & ore processing	Fuel fabrication	Fuel reprocessing	Spent fuel storage	Other
Belgium		2			1
Bulgaria				1	
Czech Republic	2				
Denmark		1			
Finland				1	
France	2	4	5	2	12
Germany	1	1		4	2
Hungary	1				
Netherlands					1
Portugal	2				
Russian Federation		3		4	2
Slovak Republic				1	
Spain	1	1			
Sweden		1		1	
Ukraine	1			1	1
United Kingdom		7	4	7	6
Total	**10**	**20**	**9**	**22**	**25**

Source: IAEA, 1996b.

Table 3.8.4. Doses from man-made sources

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
Windscala accident	2 000
Other accidents	300
Underground nuclear testing	200

Source: Bennett, 1995

2.3.3. How have radiation risks changed and how are they likely to change in the future?

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 (Figure 3.8.7). It can be seen from the table that over the next 10 years there will be an increasing number of aged operating reactors in Europe. Some of the plants that will be decommissioned will be replaced with plants with better safety features.

New advanced designs incorporate improved safety concepts and features to reduce the chance of significant releases of activity to the environment. Following these developments, it is likely that the overall risk from nuclear accidents increased in the 1970s as more plants were commissioned, but has subsequently declined in the 1990s as older plants have been taken out of service and building of new plants has slowed, with increasingly safe designs being used. How this trend will continue over the next decade is, however, uncertain. A complicating factor is the increasing deterioration of the older plants in Eastern Europe.

Safety concerns focus on certain older designs of plant, in particular the RBMK reactors of which Chernobyl was an example: 15 RBMK reactors continue to function in Russia, Ukraine and Lithuania. Implementation of improved safety plans for these reactors is delayed for a number of reasons including the lack of financial resources in these countries, despite significant assistance from the European Commission, EBRD and on a bilateral basis from individual Western countries.

The major technical causes of the Chernobyl accident were the coincidence of several deficiencies in the RBMK reactor's physical design and in the design of the emergency shutdown system. These causes were compounded by violation of operating procedures made possible by the lack of an adequate 'safety culture'. Development of safety measures have been in progress at RBMK plants since 1986, but plans to upgrade the safety of all RBMK plants are behind schedule due to economic difficulties. Accelerated implementation of this is seen as a top priority for international co-operation (IAEA, 1996e).

Newer plants will incorporate improved safety features and will be less likely to suffer severe accidents, while older plants, built to standards lower than today's will gradually be decommissioned, particularly in Central and Eastern Europe. While the result of these developments will gradually improve the risk from nuclear accidents, it is not expected that there will be a marked impact on the overall risk of accidents over the next decade. The lack of sufficiently detailed, comparable information on the risks posed by certain types of nuclear facilities, which would then allow a consistent generalised analysis, means that the overall risk to the European environment from accidental releases of radionuclides, even if small, cannot be quantified. It seems likely that the greatest hazard is presented by sites where large quantities of radioactive materials are stored and used, such as nuclear power stations, reprocessing plants and military plants. Chemical plants which produce radio-pharmaceutical products and hospitals pose lesser risks.

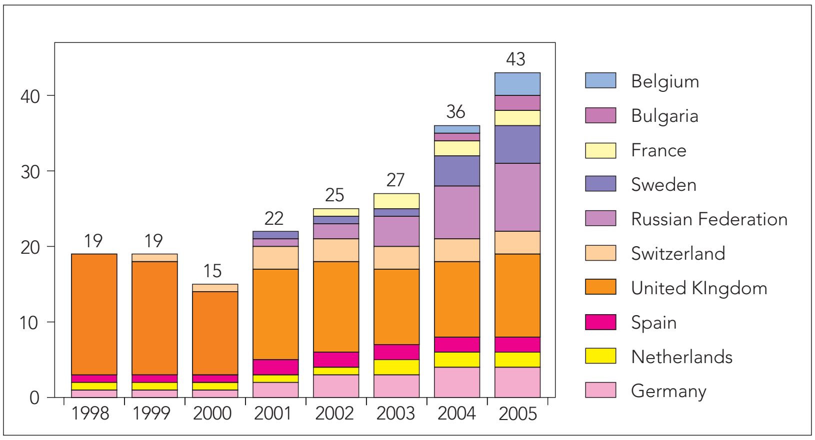
In addition to this there is the potential for accidents to occur during the disposal of radioactive sources. An increase in the numbers of accidental smeltings of industrial and medical radiation sources may occur as more sources reach the end of their useful lives. Lessons have been learnt from past accidents such as that in Goiânia, Brazil, where a caesium-137 source caused four deaths and about 20 serious exposures, and the similar incident in Estonia in 1994 when a stolen caesium-137 source irradiated 19 people. Many smelting plants that deal with scrap metal have radiation detectors to prevent this occurrence but this practice should be universal. A worldwide register of sources is being prepared by IAEA. While several incidents reported in Europe have led to radioactive contamination due to the accidental disposal of a source, they do not seem to have had significant dose implications for more than a handful of individuals.

2.4. Oil spills

World-wide, the annual number of oil spills and the total oil spilt from tankers and barges during transit and loading/discharging is showing a downward trend, as illustrated in Figure 3.8.8. The downward trend is also apparent in European waters, but is less obvious. On average, since 1970, 25% of the major spills world-wide (above 700 tonnes) have been in European waters. In the 1980s this figure was about 24%, but during the 1990s it increased to 32%.

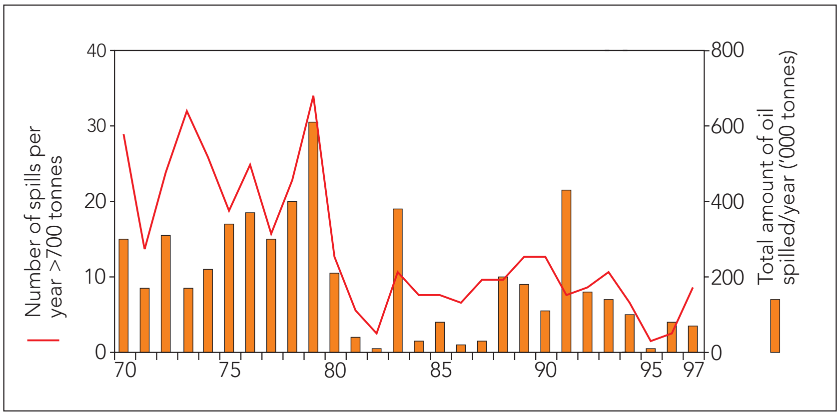
Tanker safety is a major issue on the International Maritime Organisation's marine

Operating Nuclear Power Plant Units in Europe with an Age of 30-40 Years in 1998 - 2005 — Figure 3.8.7



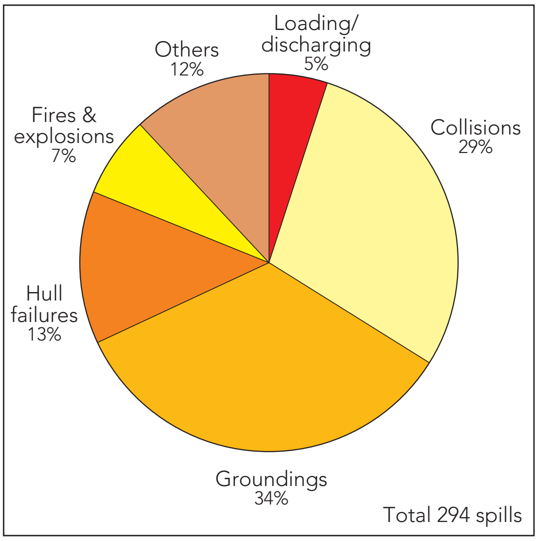
Source: IAEA Yearbook 1994 & M. Pohl, pers com

Number of oil spills world-wide and total oil spilt 1970-1997 — Figure 3.8.8



Source: ITOPF, 1998

Causes of oil spills 1970-1997 — Figure 3.8.9



Source: ITOPF, 1998

protection agenda. The bulk of the world's tankers are being fitted with double hulls or scrapped within the next few years, which is likely to reduce the likelihood of spills, although most of the world's tankers were built in the 1970s and so do not comply with many of the stricter standards introduced since. Figure 3.8.9 provides evidence of the causes of the 294 major oil spills that have occurred world-wide in 1970-1997, 76% of which were due to hull failures, collisions and groundings.

3. More management of hazards is necessary

There is no doubt that disasters will continue to occur throughout the EU. Some of these will be due to technology, some to the forces of nature, others to the combined effects of the two. Inevitably there will be loss of life and environmental damage.

However, hazards can be managed to reduce risks. Even catastrophic events can be predicted as to where they may happen, although the question of whether they will in fact happen within any given timespan (for example, the lifetime of an installation) is not predictable. Nevertheless, it is at least possible to pre-plan responses, so that loss of life and environmental impact can be minimised.

3.1. Hazard management procedures cover many industries

For many technological hazards, holistic approaches are becoming more prevalent, with increasing attention on the reduction of risk of long-term environmental impact as well as acute health and property damage from accidents. In the case of the Seveso II Directive, industrial operators must demonstrate that they have taken all the necessary measures to prevent major accidents and to limit their consequences on humans and the environment. This is likely to reduce levels of risk, especially from high-frequency, low-consequence accidents. Seveso II should also help identify the potential for low-frequency, high-consequence events, although these are by nature difficult to address.

The problem of low-frequency, high-consequence events is likely to remain a key issue in terms of risk management. However, the extent and location of the technological hazards are generally known and, as such, pre-arrangements can be made in emergency response plans. The correct response may limit the consequences of an accident by ensuring that escalation to a larger event does not occur. Lessons learnt from previous accidents should be essential research for operating companies. Testing of emergency plans at least every three years is a new requirement under the Seveso II Directive, as experience has shown that unless a plan is tested, the response during an actual accident can be inappropriate and disorganised, particularly the liaison between different groups.

There is an improved culture with regard to accident reporting and sharing the lessons learnt from accidents. Several accidents databases are already available. The improved reporting criteria (Box 3.8.4) for major accidents will result in more accidents being reported to the European Commission, and the causes, lessons learnt and preventative measures necessary to prevent a recurrence will be available to relevant bodies. This should lead to a better understanding of the issues and root causes of accidents, and, if the process is managed well, to a subsequent decrease in the number of accidents.

The European Commission's Accident database MARS is now complemented by SPIRS (Seveso Plants Information Retrieval System) (http://mahbsrv.jrc.it/spirs/Default.html). This was set up in response to Article 9 of the Seveso II Directive requiring access to information for all interested parties, including the European Commission, on the contents of the safety report for each 'Seveso Plant' in a Member State.

The main objective of SPIRS is to support the Member States in their risk management related decision-making processes by giving an insight into the geographical component

Box 3.8.4 Criteria for the notification of an accident in the Seveso II Directive

The criteria for notification of an accident relate to:

- substances involved
- injury to persons and damage to real estate
- immediate damage to the environment
- damage to property
- cross-border damage.

Source: European Community, 1997a

of risk from Seveso Plants. This is mainly done by providing a map of all Seveso Plants in the EU together with information on their hazard and risk potential. So far, SPIRS is still in a developing phase and four EU Member States have provided data on Seveso Plants in their countries on a voluntary basis for inclusion in the SPIRS prototype covering about 400 major hazardous chemical plants.

For the nuclear industry the International Nuclear Event Scale (INES) and the Incident Reporting System (IRS), both under the aegis of the International Atomic Energy Agency, are now used widely to collect information from around the world on unusual nuclear events in nuclear power plants that may be important for safety or accident prevention.

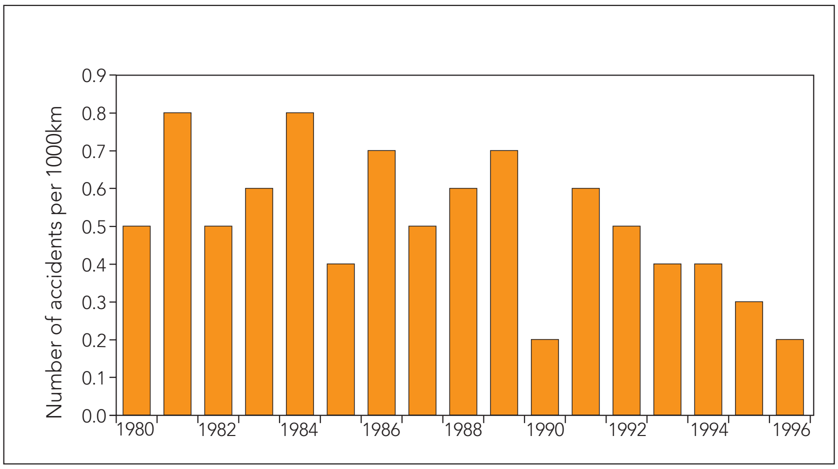
Research into the different approaches adopted in the EU for regulating technological hazards would be useful to determine if any patterns have developed, i.e. are there advantages in using a risk-orientated, goal-setting approach where the risk must be below ‘acceptable’ levels, or rather a consequence-orientated approach where prescriptive codes and standards must be met. The available data should be scrutinised in the future.

3.2. Where hazard management procedures are still needed

One area where it is difficult to predict the location of an accident is transportation. In particular, the consequences of a pipeline rupture could be severe, as a large amount of material could be released before insulation. For example, in Russia in 1989, the rupture of a gas transmission line and subsequent ignition of the flammable cloud resulted in the deaths of over 600 people on two passenger trains (Crooks, 1992). With an ever-increasing pipeline network throughout Eastern Europe, there is an increasing likelihood of such events if the risk is not managed adequately. The scope of the Seveso II Directive does not include pipelines and, thus, pipelines need to be adequately addressed in the future for an enlarged EU, although there is a downward trend in the number of accidents in Western Europe, as illustrated in Figure 3.8.10.

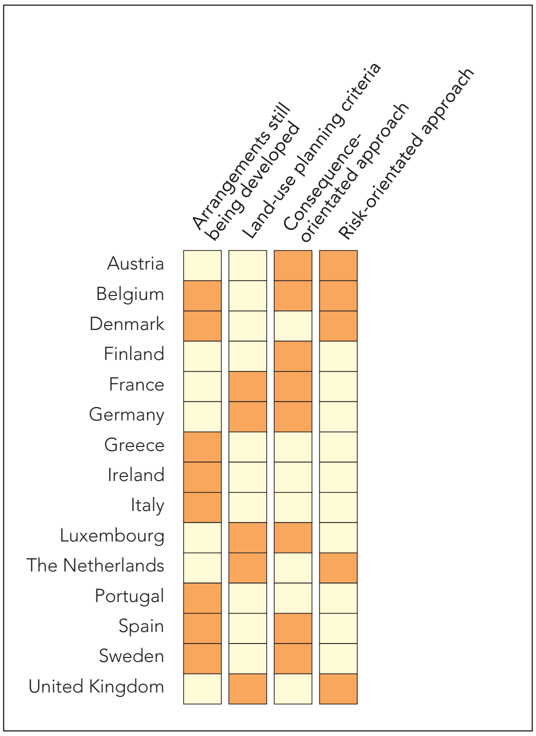
For the EU Accession Countries, the use of the Seveso II Directive would be appropriate and, encouragingly, some are already using this. The comprehensive nature of the Directive in its mandatory requirements for management of safety and the environment and its power to prohibit unacceptable activities would provide an effective model before accession. There is currently no equivalent database to MARS that covers Central and Eastern Europe, but this may change as a result of the EC’s co-operation projects (PHARE and TACIS) and the work of UN-ECE’s regional co-ordinating centres for the prevention of industrial accidents (Budapest) and for industrial accident training and exercises (Warsaw). If a data-

Number of cross-country pipeline accidents in Western Europe per 1000 km-yr, 1980-1996 Figure 3.8.10



Source: CONCAWE, 1983-1997

Regulatory approaches in the EU Figure 3.8.11



Source: updated from Smeder et al., (1996) base could be set up before accession, it would be extremely useful to see how the adoption of the Seveso II Directive affects the frequency of accidents in the Accession Countries, although the results could be confused by progressive improvements in reporting practices.

3.3. Management of natural hazards

For natural hazards, difficulties in forecasting and prediction, coupled with limited technical or behavioural responses, seem likely to lead to fewer improvements in both levels of exposure and associated damage from significant events.

As with technological hazards, the problem of low-frequency, high-consequence events is likely to remain a key risk-management issue. However, a major difference is that it is extremely difficult to predict where, as well as when, they will occur, although it is appreciated that some areas may be more susceptible to natural hazards than others, e.g. from earthquakes, flooding and landslides.

Adequate land management is essential and the management systems applied to technological hazards can be used as a model. Moreover, risk assessment and land-use planning can play a vital role in identifying, mitigating and avoiding such impacts. The use of societal risk limits could avoid the potential for large population growth in areas that are susceptible to natural hazards. Figure 3.8.11 shows the regulatory approaches in the EU and it can be seen that some Member States are already applying land-use planning criteria.

Land-use planning clearly has to take into account the environmental conditions of a particular area. While scrub clearing to create agricultural land may increase the likelihood of flooding, soil erosion and landslides in areas susceptible to heavy rainfall, it may be advantageous in forest areas that are susceptible to fires. One of the major underlying causes of forest fires is lack of land management resulting in the build-up of undergrowth that will easily ignite. However, clearing of such undergrowth to reduce the likelihood of fires must be balanced with good ecological management of the forests and in some areas it may be better from this point of view if forests were 'abandoned'.

The flood experience of some countries is forcing them to re-evaluate approaches to flood prevention and environmental security, but all such environmental considerations must be addressed for specific regions, not just those due to the hazard of flooding. A change of attitude is required, from regarding hazard prevention and response as essentially a technical problem to seeing it as part of a dynamic interaction between people and nature. The economic damage and massive social and environmental disruption that natural hazards can cause calls for more awareness and understanding of the interactions between human activities and natural systems throughout the EU and the Accession Countries.

The United Nations launched the International Decade for Natural Disaster Reduction (IDNDR 1990-2000) to make people more aware of actions to take to make themselves safe from natural disasters. Guideline principles have been drafted for natural-disaster prevention, preparedness and mitigation. 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, it does not appear that procedures have resulted in adequate responses to natural disasters in practice, and the impact on humans, the environment and the local economy has not been mitigated. Policy-makers need to investigate an overall approach to co-ordination of disaster management, and lessons learnt from previous incidents should be collected before they are forgotten, leaving the door open for disorganised response to be repeated. Real-time training exercises to prepare emergency teams for likely natural disasters would be beneficial.

3.4. There have been many initiatives following the Chernobyl accident

The Chernobyl accident alerted the international community to the potential for serious nuclear accidents to cause effects in both neighbouring countries and also those at considerable distances. Attention focused on the IAEA as a forum for obtaining agreements on nuclear safety, early notification and international response. As a result, three international conventions were developed under the auspices of IAEA:

- The Convention on Nuclear Safety was adopted in 1994, with the objective of committing participating states to a high level of nuclear safety by setting international benchmarks to which the states would subscribe. It is unusual in that there are no legal sanctions for breaking its terms, but instead States are required to submit reports to regular meetings where the reports are peer reviewed.

- The Convention on Assistance in the Case of Nuclear Accident or Radiological Emergency. This was adopted in 1986, and requires states to notify IAEA of the assistance they could provide in the event of an accident.
- The Convention on the Early Notification of a Nuclear Accident. This was adopted in 1986 and required States to report accidents at nuclear sites to potentially affected States either directly or via IAEA, and to the IAEA itself. Data essential to an assessment of the situation must also be transmitted.

Most recently, the joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management was adopted on 5 September 1997. It follows similar objectives to the Convention on Nuclear Safety and has the same procedure of reporting and peer review. IAEA has also developed revised emergency response criteria and has issued guidance on the development of national plans for emergency preparedness (IAEA, 1997). IAEA also funds education, training, technical co-operation and expert missions to aid future nuclear safety.

Following Chernobyl, the European Commission also initiated and supported projects aimed at improved data management and information transfer in the event of a future accident. A comprehensive decision support system (RODOS) is being developed with support from the European Commission as part of the procedures to improve and harmonise future accident response in Europe.

Since 1986, many countries and organisations have developed sophisticated computerised systems for gathering, managing, assessing and disseminating information about a future accident. For example, a large national network of accident monitoring stations has been established in Spain (NucNet 27/95). In the UK, the automatic monitoring network RIMNET has been developed, and the Netherlands has set up its National Radiation Monitoring (NRM) network. The German IMIS system (Integrated Measuring and Information System) is however by far the largest such network of monitoring stations in the EU. The international reporting of incidents and the sharing of information has progressed, with the IAEA Convention on Early Notification, the International Nuclear Event Scale, international emergency exercises, and initiatives such as ECURIE (European Commission Urgent Radiological Information Exchange) and EURDEP (European Radioactivity Data Exchange Platform). An enormous amount of environmental data is now being collected in various systems across Europe, generating results with a daily volume of hundreds of gigabytes. The major development now required is to make these systems communicate with each other and to provide appropriate information to non-specialists.

A Centre for Information and Valorisation of European Radioactive Contaminated Territories (CIVERT) has been established at the Environment Institute of the EC's Joint Research Centre, Ispra, with the aim of providing assistance to local and national authorities in managing large contaminated areas in the event of a future accident.

Guidance on food intervention levels have been developed to ensure food safety in Europe in the event of food being contaminated after a future accident. The EU has issued regulations (European Commission – Euratom) that will apply in Europe in the event of a future accident, containing maximum permitted activity concentrations for contamination in marketed food. Further regulations deal with food imported from and exported to countries outside the EU. In addition to these, there are Codex Alimentarius Council (CAC) guideline levels developed by FAO/WHO for food moving in international trade (codex, 1989). IAEA and WHO have also issued advice on intervention levels in food. These levels issued by the EC, CAC, IAEA and WHO are not entirely consistent, and therefore despite attempts to harmonise action levels following a future accident, the potential for inconsistency remains. In the longer term after an accident, many different types of action may be taken to reduce the transfer of radionuclides to food products. Practical advice on these is at present country-specific.

EU radiation protection legislation is summarised in the Community Radiation Protection Legislation (European Commission, 1996c) and includes the legislation under the provisions of the Euratom Treaty.

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