REVIEW

The human health consequences of flooding in Europe and the implications for public health: a review of the evidence

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Abstract: In Europe, floods are the most common natural disaster. The adverse human health consequences of flooding are complex and far-reaching. The main health effects include drowning, injuries and, perhaps most importantly with floods in Europe, an increased incidence of common mental health disorders. Anxiety and depression may last for months and possibly even years after the flood event and so the true health burden is rarely appreciated. The effect of floods increasing the risk of communicable diseases appears relatively infrequent in Europe. The vulnerability of a person or group to a natural hazard is defined in terms of their capacity to anticipate, cope, resist and recover from the impact of the disaster. Determining vulnerability is a major challenge. What little research literature there is on this subject indicates that certain groups within communities (eg the elderly, disabled, children, women, ethnic minorities and those on low incomes) may be more vulnerable to the effects of flooding than others. However, there is a need for more good-quality epidemiological data before vulnerability indices could be used operationally to minimise the effects of flooding. With better information available, the emphasis in disaster management could shift from post-disaster improvisation to pre-disaster planning. A comprehensive, risk-based emergency management programme of preparedness, response and recovery has the potential to reduce the adverse health effects of floods, but there is currently inadequate evidence of the effectiveness of such schemes.
Keywords: floods, mental health, climate change, Europe

Introduction

In Europe, floods are the most common natural disaster and in recent years have received much media attention. European vulnerability to flooding was highlighted by the loss of life and economic damage from flooding events of the Rhine, Meuse, Po and Oder rivers in the 1990s and in the UK floods of 2000. In addition, summer flooding of the Elbe and Danube rivers in 2002 resulted in some of the worst floods seen in Europe for more than a century (Figure 1).

Various mechanisms may cause flooding, and different flood characteristics affect the occurrence and severity of the flood event (Malilay 1997). The third assessment report of the Intergovernmental Panel on Climate Change (IPCC) concluded that by 2100 the predicted pattern of changes in annual precipitation over Europe is for widespread increases in northern Europe (between +1% and +2% per decade), smaller decreases across southern Europe (maximum −1% per decade) and small or ambiguous changes in central Europe (IPCC 2001). It is likely that intense precipitation events will continue to increase in frequency, especially in the winter. Further to this, the frequency of great floods has been demonstrated to have increased substantially during the twentieth century (Milly et al 2002). This pattern is consistent with current climate models, with the models suggesting that the trend will continue. These projected climate changes underscore the need to increase the development and implementation of measures to prevent adverse health impacts from flooding (Baxter et al 2001).

This paper reviews the epidemiological literature to assess the human health consequences of flooding in Europe and other industrialised countries, and investigates the current adaptation strategies available to the health sector to minimise the effects.

Methods

The search for literature on the health effects of floods was restricted to events in the following regions: the whole of Europe, North America and Australasia. Although the focus of this work is to document the effects of flood events in

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Figure 1 2002 summer floods in Dessau, Germany. Source: Maike Just/The German Red Cross. Copyright: with kind permission of The German Red Cross.

Europe, examples from other industrialised countries are also used to illustrate the potential range of health impacts from floods. Events from low-income countries are excluded as the effects can be very different to those experienced in the majority of Europe. Literature was obtained by consulting experts in the field and by searching databases using the following search strategy:

- Objective: to search for literature relating to the human health impacts of flooding
- Database list: BIDS, Embase, PsycLIT, PubMed, Sigle
- Terms searched for: flood, floods, flooding, disasters, extreme events, health
- Inclusion criteria: all available years
- Exclusion criteria: events not occurring in Europe, North America or Australasia.

Results

There are two main types of river floods that affect Europe (Penning-Rowsell and Fordham 1994). First, there is the rapid rise flood. These are most commonly associated with intense thunderstorm activity and so tend to be mainly local or regional events. Second, there are the slow rise events characterised by floods on the large rivers of northern Europe, notably the Rhine, Vistula, Thames, Seine, Loire and the Rhone (Penning-Rowsell et al 1996). These large catchments respond to prolonged periods of rainfall or snowmelt. In addition, there is also a risk of coastal flooding due to sea level rise, the effects of which will greatly impact on low-lying coasts and islands. Different types of floods affect human health in different ways.

The adverse human health consequences of flooding are complex and far-reaching (Ohl and Tapsell 2000) and can therefore be difficult to attribute to the flood event itself. The health impacts are broadly categorised into one of two groups:

1. Physical health effects sustained during the flood event itself or during the clean-up process, or from knock-on effects brought about by damage to major infrastructure including displacement of populations.
2. Mental health effects directly occurring due to the experience of being flooded, or indirectly during the restoration process.

Both of these types of health effects are discussed in more detail below.

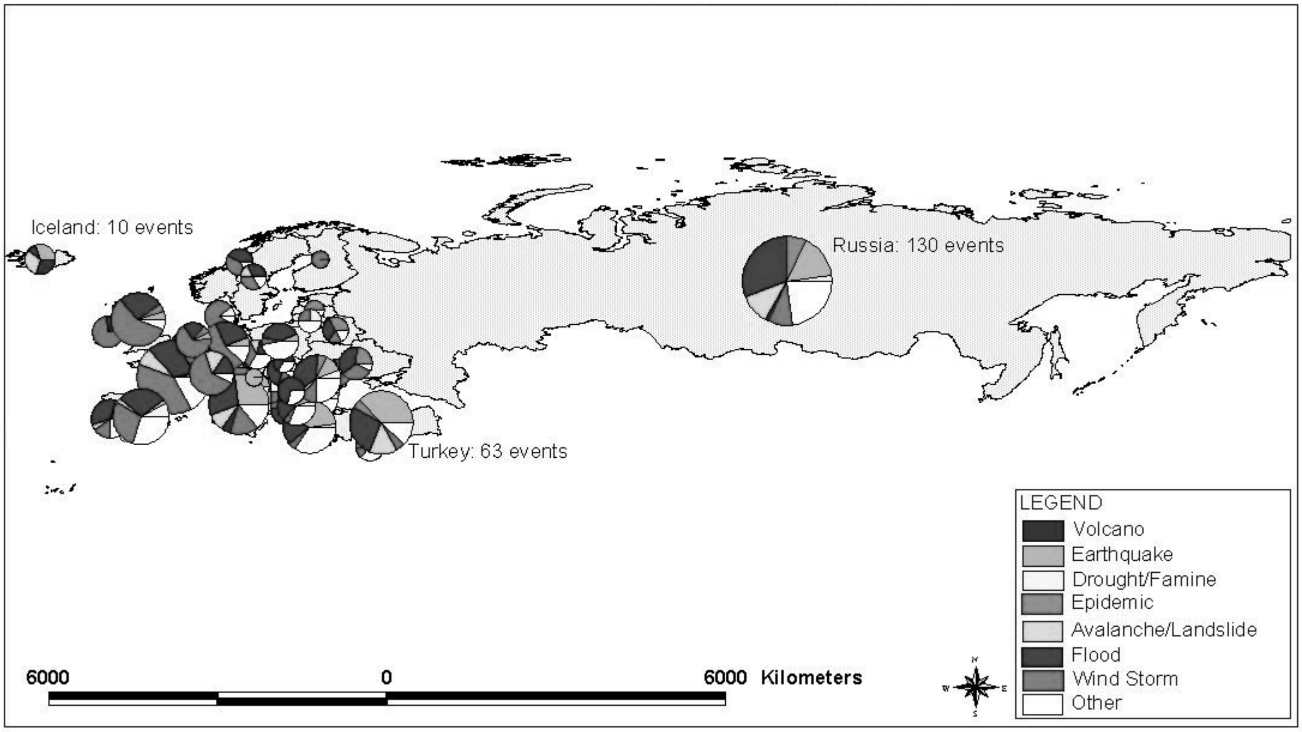
Physical health effects

A database of the occurrence and immediate effects of all reported mass disasters, including flood events, in the world from 1900 to present is available from EM-DAT: the OFDA/CRED International Disaster Database (http://www.cred.be/emdat/). The database is compiled from various sources including United Nations (UN) agencies, non-governmental organisations, insurance companies, research institutes and press agencies. For a disaster to be entered onto the database, at least one of the following 4 criteria has to be fulfilled: 10 or more people reported killed, 100 people reported affected, a call for international assistance or declaration of a state of emergency. Figure 2 shows the distribution of all natural disaster types in Europe recorded on EM-DAT between 1975 and 2001. This shows that floods are likely to be a major concern for many countries in Europe. Since 1975, 238 flood events in Europe have been recorded on EM-DAT, resulting in 2476 reported fatalities. Between 1980 and 1999, an annual rate of 1.3 deaths and 5.7 injuries have occurred per 10 000 000 population due to inland floods and landslides in Western Europe (McMichael et al 2002). Table 1 presents the ten most disastrous floods in Europe between 1990–2001 in terms of the number of deaths caused. The date and location of each flood event is provided, as well as the number of people killed. The floods of 2002 would appear among the list were this information available on EM-DAT at the time of writing this paper.

Over the years, the physical health effects of flooding in Europe have been documented in the medical literature when major flood events have occurred (Lorraine 1954; Cervenka 1976). In more recent decades, the number of studies looking at the health effects of such events has increased. This work is examined separately for different outcomes below.

Mortality

Most flood-related deaths can be attributed to rapid rise



EM-DAT: The OFDA/CRED International Disaster Database
(http://www.cred.be ; email: cred@epid.ucl.ac.be)

Figure 2 Distribution of natural disasters, by country and type of phenomenon, in Europe (1975–2001). Copyright: with kind permission of CRED.

floods, due to the increased risk of drowning (French et al 1983). In October 1988, a flash flood occurred in the Nimes region of France (Duclos et al 1991). Although the homes of 45 000 people were damaged and more than 1100 vehicles destroyed, only 9 deaths by drowning (including two people who tried to rescue others) and 3 severe injuries were reported. The limited death toll can be attributed to the fact that the disaster occurred early in the morning when most people were still home, and also because of the mild temperature, government rescue plans and, most of all, because of rescue operations conducted by civilians. Other health problems and injuries during the post-impact phase may have been reduced as a result of the response by trained military personnel and by the distribution of boots and gloves to other responders. In 1996, 86 people died from a flood in the town of Biescas in Spain as a consequence of a stream of

Table 1 The 10 most disastrous floods in Europe (based on number of deaths) between 1990–2001, as recorded by the EM-DAT International Disaster Database

Country	*Year*	*Flood start date (month, day)*	*Number of deaths caused*	*Location*
Tajikistan	1992	May 25	1346	–
Italy	1998	May 6	147	Campania region
Russia	1993	June 17	125	Yekaterinburg region (Sverdlovsk)
Romania	1991	July 28	108	Bouriatie, Ulan-Ude
Uzbekistan	1998	July 8	95	Shahimardan, Yerdan
Turkey	1995	November 4	78	Izmir, Antalaya, Isparta
Turkey	1995	July 10	70	Ankara, Istanbul, Senirkent
Italy	1994	November 5	64	Piedmont region, Liguria region
Turkey	1998	August 10	60	Beskoy (Trabzon province)
Tajikistan	1998	April 23	57	Ragun, Ainy, Old Mastchoh, Shahrinav, Muminabad, Penjikent, Kuliyab Central, Vose, Dushanbe, Tursenzade, Varzob, Farhor, Baljuvon, Tursunzade, Leninski, Gissar, Kanibadam, Sharristan, Kurgantube, Kaarnikhon, Khovaling

water and mud that suddenly covered a campsite located near a channelised (artificially directed) river (Marcuello and Estrela 1996). During the 1998 flood in Sarno, Italy, there were between 147 and 160 fatalities caused by a river of mud that destroyed an urban area (Thonissen 1998).

Many slow-rise river flood events have also been associated with fatalities. At the end of 1993 and the beginning of 1994, overflow of the river Meuse and of the middle and lower Rhine caused 10 deaths in Germany and other affected countries (Bayerische Ruckversicherung 1996a). Thirteen months later, intense rainfall produced a new flood with similar characteristics. The effects, however, were not so great because people were aware of the risk and better prepared (Bayerische Ruckversicherung 1996b).

In 1997, river floods in central Europe left over 200 000 people homeless, and more than 100 people were killed (Kriz et al 1998; Saunders 1998). The main countries affected were Poland, Germany and the Czech Republic.

In the United Kingdom (UK), the effects of floods have been well documented. On Saturday 31 January and Sunday 1 February 1953, a great storm surge, accompanied by gale force winds, swept over the north of the UK causing widespread flooding of coastal areas (Greave 1956). The worst effects were in Canvey Island where 58 people died, although it was also noted that the death rate climbed significantly during the 2 months following the disaster, as compared with the same 2 months the previous year (Summers 1978). In total, 307 people in the UK died due to the event, in addition to 1795 people in the Netherlands. Other examples in the UK include 5 fatalities in the central England and Wales floods of 1998. Three people drowned in Glasgow in 1994; 4 people drowned in south Wales in 1979; and in 1975, 2 people drowned and 2 were struck by lightning during a severe thunderstorm in Hampstead, London, where floods caused houses to be damaged, cars to float along streets, subways to fill and sewers to burst (Faulkner 1999).

Injuries

Comprehensive surveillance of morbidity following floods is limited, but following the 1993 Midwestern United States floods, surveillance of flood-related morbidity was undertaken (CDC 1993). Five hundred and twenty-four flood-related conditions were reported in emergency departments. Of these, 250 were injuries, 233 were illnesses, 39 were listed as 'other' and two were 'unknown'. Of the 250 reported injuries, the most common were sprains/strains, lacerations, 'other injuries' and abrasions/contusions.

Illnesses from flood-induced contamination of water supplies

There is a small risk of communicable disease outbreaks following flooding, although severe occurrences are rare in industrialised countries due to the public health infrastructure in place prior to and following a flood event, such as water treatment and effective sewage pumping. One example of an outbreak is that of leptospirosis which occurred after the flooding in the Czech Republic in 1997, although the quality of the data appears to be poor (Kriz et al 1998). A total of 14 water-borne epidemics occurred in Finland during 1998–1999, resulting in about 7300 registered illness cases (Miettinen et al 2001). Thirteen of the epidemics were associated with undisinfected ground water in mostly flood-induced outbreaks. Boiling of drinking water was one of the first actions taken in almost all of the outbreaks. Infectious disease outbreaks following flooding may be more common in tropical regions of industrialised countries such as Australia, where conditions such as melioidosis and other vector-borne diseases have been linked to local flooding (Munckhof et al 2001).

No specific increase in infectious disease was observed following the 1988 flash flood in Nimes, France (Duclos et al 1991), and no increase in the incidence of acute gastroenteritis or other possibly flood-related communicable diseases was observed following the 1995 river floods in eastern Norway (Aavitsland et al 1996). This was attributed in part to measures such as maintaining safe drinking water and providing information on safe management of flood water during evacuation and clean-up. Similarly, another report stated that no dramatic increase in water-borne diseases was reported or documented in the aftermath of the major floods of the 1970s, although the attitude of the public, the mass media and of the health services sometimes led to ineffective mass immunisations (de Ville de Goyet 1977). The author stated that an epidemiological system and accurate information on the actual situation are essential in cases of major disasters.

Other flood-induced illnesses

Chronic health effects (including respiratory problems) secondary to a flood disaster have been documented in the literature. Investigation of leukaemias and lymphomas in western New York State found an apparent space-time clustering of cases that began 2 years after major floods occurred in the Canisteo River valley in 1972 (Janerich et al 1981). This, in conjunction with a marked increase in rates of spontaneous abortion, suggested an unidentified flood-related environmental exposure. Possible explanations provided by the authors include exposure to human and animal viruses during evacuation, or perhaps because of substantial psychological or physical stress experienced by people at the time of the flood.

Following the flash flood in Nimes in 1988, 12 cases of carbon monoxide poisoning were reported involving firefighters, civilians and members of the military who were pumping water and effluent from basements (Duclos et al 1991). There are reports of outbreaks of scarlet fever in Moldavia following floods (French 1989). Authors of a case study of heavy metal soil contamination after the flooding of the river Meuse during the winter of 1993–1994 concluded there was a potential health risk for riverbank inhabitants as a consequence of lead and cadmium contamination of the flood-plain soils (Albering et al 1999). There is also the risk of toxic fungal spread as a result of flooding, both in houses following home water damage (Jarvis et al 1998) and as an agricultural pest (Rosenzweig et al 2001).

Following the 1968 flooding in Bristol, Bennet (1970) reported a 50% increase in mortality ($p < 0.02$) in the homes of people who were flooded, with many of these deaths being from chronic diseases such as cancer. The author observed similarities with the pattern of health and mortality after bereavement, and argued that the effect of flooding upon mortality and ill-health is largely a result of distress and the psychological effects of the event.

Mental health effects

Comparison of rates of mental ill-health between studies are hampered by the varying definitions of outcome used. Some investigators focus on post-traumatic stress disorder (PTSD) as a specific entity, some use rates of common mental disorders such as anxiety and depression, whereas others use standard instruments such as the General Health Questionnaire which do not give a specific diagnosis. There is no doubt however, that flooding, in common with other traumatic life events, is associated with increased rates of the most common mental disorders: anxiety and depression (Bennet 1970; Sartorius 1990). Aside from the experience of being flooded, many of the mental health problems stem from the troubles brought about by geographic displacement (Fullilove 1996), damage to the home or loss of familiar possessions (Keene 1998), and also the stress involved in dealing with builders and other repair people during the aftermath (Tapsell and Tunstall 2001). In this context, lack of insurance may be an important factor in hindering recovery. Lack of insurance (or under-insurance) was a common factor in exacerbating the impacts of the 1993 floods in Perth, Scotland (Fordham and Ketteridge 1995).

A panel study of over 200 elderly adults interviewed both before and after the floods in southeastern Kentucky, US, in 1981 and 1984 found that flood exposure was related to modest physical health declines such as functional impairment and fatigue (Phifer et al 1988). The study also demonstrated that persistence of flood-related health effects was directly related to flood intensity: whereas the effects of the 1981 flood were generally limited to the first year post-flood, the more severe 1984 flood continued to have a significant impact 18 months after the flood. Men, those with lower occupational status, and persons aged 55–64 were at significantly greater risk of suffering from flood-related psychological symptoms. Sociodemographic status did not moderate the impact of flood exposure on physical health (Phifer 1990).

A case study of the health effects of flooding in Uphill, UK, showed a consistent pattern of increased psychological problems amongst flood victims in the five years following floods (Green et al 1985). Following the Lewes floods in the UK in 2000, higher levels of depression (as measured by General Health Questionnaire scores) were demonstrated among flooded households compared to controls in the same area (Hepple 2001). Also in the UK, a qualitative study one year after the Banbury and Kidlington floods revealed continuing psychological health effects among most of those interviewed (Tapsell and Tunstall 2000). There was also the suggestion that the full health impacts of the floods had not been manifested at the time of the study. It is often only after people's homes have been put back in order that the full realisation of what has happened to them is appreciated.

A pilot cross-sectional study based on the 1992 floods in the Vaucluse, France, was conducted using randomly selected households in two affected towns (Verger et al 1999). This study demonstrated that an investigation into the long-term psychological consequences of an environmental disaster could be carried out several years after the event but that the feasibility of such a study would depend ultimately on its acceptance by the public and the relevant authorities. Another pilot study, looking at the effects of the Netherlands flood of 1994–1995 on the health and wellbeing of exposed subjects, suggested 15%–20% of children were having moderate to severe 'stress' symptoms, and 15% of adults still experienced very severe 'symptoms of stress' 6 months after the event (Becht et al 1998).

An increase in psychosocial symptoms and PTSD including 50 flood-linked suicides were reported in the two months following the major floods in Poland in 1997 (IFRC 1998). Based on interviews with Polish children aged 11–14 years, these floods were also reported to be associated with long-term PTSD, depression and dissatisfaction with ongoing life (Bokszczanin 2000). In addition, psychosocial stress observed in the Klodzko region of Poland caused hypothalamic amenorrhoea in some female adolescents (Neuberg et al 1999).

By contrast, study of a psychiatric outpatient department after the 1997 floods in the Czech Republic suggested there were *fewer* hospital admissions during the investigation period than in other years, and no suicides or attempted suicides were recorded (Kucerova 1999). The author suggests that the absence of suicidal activities may have been caused by a development of positive attitudes of individuals towards themselves and others as a result of the extensive disaster, such as is often observed during times of war.

Contact with health services

Contact with health services may increase following a flood event, although a further effect of floods upon health could be the likely disruption of 'normal' health and social service programmes. These services are likely to be heavily involved in the aftercare of a disaster, thus removing them from their normal caring activities.

The impacts of flood events on the use of primary and secondary health services have not been extensively investigated in the UK or elsewhere. Primary care attendance following the Bristol 1968 flood rose by 53%, and referrals and admissions to hospitals more than doubled (Bennet 1970). Similarly, the number of visits to general practitioners, hospitals and specialists were all significantly increased for flooded persons in the year following the 1974 Brisbane, Australia, floods (Abrahams et al 1976).

Vulnerability

'Vulnerability' is defined in terms of the capacity of a person or group to anticipate, cope with, resist and recover from the impact of a natural hazard (Blaikie et al 1994). Certain groups within communities (eg the elderly, disabled, children, women, ethnic minorities and those on low incomes) may be more vulnerable than others to the effects of flooding (Ketteridge and Fordham 1995; Thompson 1995; Curle and Wiliams 1996; Ticehurst et al 1996; Flynn and Nelson 1998; Fordham 1998; Morrow 1999; Tapsell and Tunstall 2001). Consequently, these groups may suffer greater effects from a flood and may need special consideration by the authorities during the response and recovery periods. However, much of the work is qualitative in nature and robust estimates of differences between groups based on epidemiological studies are lacking.

People on lower incomes may be more vulnerable to the effects of a flood in that they may not have adequate insurance or the financial capacity to recover from the experience. Lack of resources can impede resilience to a disaster, as savings or other financial resources can be used as a buffer against the worst tangible and intangible impacts of a flood (Ketteridge and Fordham 1995). Health is affected by the places in which people live, work and interact, and yet many epidemiological studies overlook the characteristics of places and instead focus solely on the people who inhabit them (Smoyer 1998).

Environmental disasters can be particularly devastating to already vulnerable populations such as the homeless and migrants, who, because of social, political and economic constraints, experience special health care needs. In the US, a synthesis of past disaster research showed how various racial and ethnic groups may be differentially affected, both physically and psychologically, and how disaster effects vary by race and ethnicity during the periods of emergency response, recovery and reconstruction (Fothergill et al 1999). The authors suggest that racial and ethnic communities in the US such as African Americans and Mexican Americans are more vulnerable to natural disasters due to factors such as language, housing patterns, building construction, community isolation and cultural insensitivities of the majority population. A variety of other studies have also demonstrated vulnerability of subgroups (Huerta and Horton 1978; Green 1988a, 1988b; Gulitz et al 1990; Green et al 1994; Ohl and Tapsell 2000; Enarson and Fordham 2001).

To ascertain vulnerability, the public health consequences of disasters need to be properly evaluated (Logue et al 1981; Blake 1989; French 1989; Lechat 1990a, 1990b; Kirchsteiger 1999). However, an assessment of human health impacts is complicated due to numerous uncertainties, including the lack of good-quality epidemiological data, and the unknown economic, political and technological response of society (Jendritzky 1998).

Strategies to reduce flood impacts

Before, during and after a flood event, activities may be undertaken by the population at risk, by policy makers and by emergency responders to reduce health risks. Traditionally, the fields of engineering and urban planning aimed to reduce the harmful effects of flooding by limiting the impact of a flood on human health and economic infrastructure. This is accomplished by building codes, legislation to relocate structures away from flood-prone areas and planning appropriate land use. Mitigation measures may reduce but not eliminate major damage. Early warning of flooding risk, and appropriate citizen response, has been shown to be effective in reducing disaster-related deaths. From a public health point of view, planning for floods during the inter-flood phase aims to enable communities to effectively respond to the health consequences of floods and to enable the local and central authorities to organise and effectively coordinate relief activities, including making the best use of local resources and properly managing national and international relief assistance. In addition, medium- to long-term interventions may be needed to support populations who have been flooded. These should include initiatives such as public health authorities being alerted to the possibility of post-flood diseases and injuries, and the identification and provision of health services for individuals with post-flood mental health problems. Currently, however, it is unclear whether the mental health impacts will respond best to psychological and/or pharmacological interventions delivered through health services or whether the interventions would best be targeted at providing financial or other assistance such as with housing.

It seems likely that effective vulnerability reduction will necessitate the involvement of a range of sectors at the local, regional and sometimes national level. There is a need for statistical indicators of vulnerability and the harm caused by major natural disasters. Data from these indicators will assist in monitoring and evaluating vulnerability reduction, and identification of communities at risk. It is important that approaches to disaster relief, preparedness and mitigation start with programmes with a developmental focus on increasing the health and safety of the potentially affected populations (McCluskey 2001). An overall objective of disaster epidemiology should be to describe the health effects of disasters and the factors contributing to these effects (Noji 1992, 1995, 1996, 2000) Results of epidemiological studies of natural disasters provide clues to diagnosis, help medical care providers match resources to needs, and permit better contingency planning (Binder and Sanderson 1987).

Discussion and conclusions

Despite floods being the most common natural disaster in Europe, the health risks associated with flooding are surprisingly poorly characterised. This review highlights the dearth of good quantitative data available on the health effects of flooding, resulting in uncertainty in the full range of potential health impacts of flood events. The studies that have been conducted mainly concentrate on assessing effects of large events, even though more frequent smaller events may have more of a health impact. Different types of floods may need different types of interventional strategies to minimise impacts. In general, the reviewed reports suggest two main messages when considering the health impacts of floods in industrialised countries:

1. The biggest impacts occur as a result of the psychological distress experienced during flooding and in its aftermath.
2. In direct contrast to low-income countries, the likelihood of infectious disease outbreaks following flooding in temperate industrialised countries are low. Maintenance of existing public health responses to flooding in these countries are important to sustain the low risk.

A better understanding is needed of vulnerability risk factors. There are suggestions that some people may be more susceptible to the effects of floods than others, but the available evidence is insufficient to allow vulnerability indices to be devised and used operationally. Again the need is for more and better quality epidemiological data, including:

- centralised and systematic national reporting for deaths and injuries from floods using standardised methodology;
- development of instruments to assess health risks;
- identification of data needed to prepare for and evaluate the impacts of such strategies on future flood events.

There are methodological problems associated with mounting retrospective studies. Such studies are likely to be prone to recall bias as affected subjects may be more likely to remember adverse effects. In addition, the selection of a suitable control population is required to assess the true effects attributable to the flood disaster. It has been suggested that surveillance of flood-related morbidity, mortality, vector populations and environmental health should continue throughout the response and recovery periods (Malilay 1997). Should any unusual conditions be noted, specialised investigations or surveys should be conducted so that appropriate interventions can be made.

The frequency of extreme weather events such as floods is most likely on the increase due to changes in the world's climate (Fulton 1999). Significant reductions in greenhouse gas emissions need to be made; however, the impact of such reductions would only become apparent in 50–100 years time. Preparations should be made for the climate change that is on its way as a result of the greenhouse gases that are already in the atmosphere (Parry et al 1998). As a consequence, more emphasis needs to be placed on available structural and policy-oriented flood control measures, and on the activities undertaken by the population at risk and by emergency responders before, during and after a flood event to prevent or reduce the risk of flood-related injury, illness or death.

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