Title:	**Loss of life caused by floods: an overview of mortality statistics for worldwide floods**				
Author:	Ir. S.N. Jonkman		Institute:	Rijkswaterstaat, Dienst Weg- en Waterbouwkunde	
					June 2003
Number of pages	:	13.			
Keywords (3-5)	:	floods, loss of life, flood mortality, health effects			
DC-Publication-number	:	DC1-233-6			
Institute Publication-number (optional)	:				
Report Type	:	☒	Intermediary report or study		
	:	☐	Final projectreport		
DUP-publication Type	:	☒	DUP Standard		
		☐	DUP-Science		

Acknowledgement
This research has been sponsored by the Dutch Ministry of Transport, Public Words and Water Management.

Other Research project sponsor(s):

Abstract

Every year floods cause enormous damage all over the world. Furthermore floods can have substantial impacts on public health, and indirectly lead to a decrease of socio-economic welfare. In the working paper "health effects of floods", which is included in the appendix, an overview of the various types of health effects has been given and information from the health effects occurring during or after flood events has been summarized. This investigation shows that injuries, illnesses, diseases and mental health effects can occur after flooding.

The main part of this study focuses on loss of life. Figures are presented on general mortality for worldwide floods. The results show that the mortality associated with a flood events will strongly depend on the flood characteristics, i.e. on the flood type. Also the way people respond to the exposures is a critical factor in the morbidity and mortality associated with such events. Also causes of flood mortality have been studied, an overview of findings from the analysis of flood cases is given in the report. Especially in European floods, the loss of life is to a large degree associated with risk-taking behaviour.

For prevention of flood health effects more insight in the causes due to which flood deaths occur is necessary. Based on a limited number of case studies a first analysis of death causes is given. However, the empirical evidence for the relevance of the different death causes is rather weak. Also the knowledge on the non-lethal effects associated with floods is limited. Therefore there is a need for more and better quantitative data on health impacts associated with all categories of flooding. This includes centralized and systematic national reporting of deaths and injuries from floods using a standardized methodology.

The results of these studies may provide some insights in the potential magnitude of flood events and can aid the development of vulnerability indicators for flood hazards. Insights gained can provide background for decision making on the desired level of flood protection and the application of measures to prevent flood deaths.

PROJECT NAME:	**Flood consequences**	PROJECT CODE:	**02.03.03**
BASEPROJECT NAME:	**Flood consequences and acceptability**	BASEPROJECT CODE:	**02.03**
THEME NAME:	**Risk of flooding**	THEME CODE:	**02**

Executive Summary

Every year, floods cause enormous damage all over the world. In the last decade of the 20th century floods accounted for about 12% of all deaths from natural disasters, claiming about 93,000 fatalities (source: OFD / CRED international disaster database). In the Netherlands, the hazard of large-scale floods leading to extensive damage and loss of life is always present, since large parts of the country lie below sea-level. In this sub-project, part of the Delft Cluster "consequences of floods" project, the matter of loss of life caused by floods is investigated. Since it appeared from a review of international literature that the knowledge on this subject is very limited, the problem is approached at various levels of detail. The aims of this subproject are twofold: generating knowledge of loss of life caused by floods by "learning" from the events during international floods, and, secondly, to improve the methods for estimation of loss of life caused by floods for the specific situation in the Netherlands.

In the first part of the study statistics on loss of life in worldwide floods are analysed. Also the occurrence of other, non-lethal health effects, is investigated. The second part proposes a framework for the estimation of loss of life caused by floods in the Netherlands. Finally, special attention is given in the third part to the possibility of additional fatalities resulting from the flooding of industrial sites. The main results of each of these three subprojects are summarized below

1. Loss of life caused by floods: an overview of mortality statistics for worldwide floods
Floods can have a substantial impact on public health, and indirectly lead to a decrease of socio-economic welfare. In this report the effects of worldwide floods on human well-being are studied.

A review of international literature on flooding health effects and information from case studies was conducted. This investigation shows that injuries, illnesses, diseases and mental health effects can occur after flooding. Especially psychological effects can continue to last for months and even years after the flood and are therefore an important consequence.

The main part investigates loss of life statistics for different types of floods and different regions with general information from the OFDA / CRED international disaster database concerning a large number of worldwide flood events. Figures are presented on mortality for worldwide floods. The results show that the mortality associated with flood events strongly depends on the flood characteristics, such as the available time for evacuation and the rate of rising of the flood waters , i.e. on the flood type.

Also, causes of flood mortality have been studied with detailed information on flood fatalities for a limited number of cases. In general, it can be stated that the way people respond to the exposures is a critical factor in the morbidity and mortality associated with such events. Especially in European floods, the loss of life is to a large degree associated with risk-taking behaviour.

However, the insight in health effects of floods, both morbidity and mortality, is limited. This outlines the need for more and better quantitative data on health impacts associated with all categories of flooding. This includes centralized and systematic national reporting of deaths and injuries from floods using a standardized methodology.

2. Consequences of floods: the development of a method to estimate the loss of life
In this part a framework for the estimation of loss of life caused by floods in the Netherlands is proposed. The method takes into account the effect of evacuation during the flood and various mechanisms which lead to fatalities during a flood. The relationships between flood characteristics and number of fatalities are based on data from the 1953 disaster, during which the south-western part of the Netherlands was flooded, and that caused 1836 fatalities. The method is applied in two case studies to give a first estimate of the number of fatalities caused by a river dike breach near Rotterdam and failure of the coastal defence near Katwijk, both leading to a flood of the Central Holland area. The results indicate that, contrary to what is generally believed, river floods may cause more fatalities tha coastal floods. This mainly depends on the topography and elevation of the flooded area and the period during

which inflow takes place. To further improve the method for estimation of loss of life, knowledge generated on drowning causes can be applied. Also the modeling of evacuation before and during the flood requires significant improvement.

3. Casualties resulting from flooding of industrial sites
Aim of this part of the study was to get insight into the number of possible casualties that could be expected as a con-sequence of flooding of industrial sites. First a literature study was carried out using a database containing more than 17000 industrial accidents. From the literature study it could be concluded that only high-energy floods (i.e. high flow velocities) (were reported to) cause calamities (like fire and explosions) with casualties. Floating of tanks was observed in certain cases, and in addition to (storage) tanks, pipelines were vulnerable objects. No effects of toxic sub-stances released and subsequently dispersed as a result from floods are reported. Secondly, a calculation of the expected number casualties was carried out for a simulated flooding event near the city of Krimpen aan de Lek in the Netherlands, using generally recognised principles and models applied during quantitative (safety) risk assessment studies (software programme EFFECTS version 5). Only one site, where sufficient amounts of dangerous substances were stored, was found to be located such that a significant release could be expected. This was a location where 86 tons of ammonia (NH_3) was pre-sent. Under unfavourable atmospheric conditions release of this volume could result in over 2000 deaths, and many more people needing medical attention. More realistic conditions, under which a dyke breach could be expected, could result in about 55 casualties. Although flood conditions might be such that a re-lease could occur, local (safety) measures taken significantly reduce the probability of occurrence of such a scenario. Although the effects of chemical releases can be estimated, the likelihood of the occurrence of such events should be investigated further in a probabilistic approach.

Concluding remarks
Finally, it can be stated that as a result of this subproject more knowledge is generated on the main factors influencing loss of life due to floods. The results of these studies provide some insights in the potential magnitude of flood events and can aid the development of vulnerability indicators for flood hazards. Insights gained can provide background for decision-making on the desired level of flood protection and the application of measures to prevent flood deaths. The research on loss of life caused by floods will be continued in an ongoing PhD study at Delft University.

PROJECT NAME:	**Flood consequences**	PROJECT CODE:	**02.03.03**
BASEPROJECT NAME:	**Flood consequences and acceptability**	BASEPROJECT CODE:	**02.03**
THEME NAME:	**Risk of flooding**	THEME CODE:	**02**

Table of contents

Introduction

Every year floods cause enormous damage all over the world. In the last decade of the 20th century floods accounted for about 12% of all deaths from natural disasters, claiming about 93,000 fatalities[1]. Furthermore floods can have substantial impacts on public health, and indirectly lead to a decrease of socio-economic welfare. In the working paper "health effects of floods", which is included in the appendix, an overview of the various types of health effects has been given and information from the health effects occurring during or after flood events has been summarized. This investigation shows that injuries, illnesses, diseases and mental health effects can occur after flooding.

However, this study focuses on loss of life caused by floods. Studies carried out in the past have focussed on the general documentation of various natural disasters on a worldwide scale (Berz, 2000) or the analysis of flood fatalities for a specific country, for example for Australia (Coates, 1999). However, a study which analyses loss of life statistics for worldwide floods in relation with their characteristics is not yet found in literature. Therefore this study investigates loss of life statistics for different types of floods and different regions with general information from the CRED disaster database concerning a large number of worldwide flood events.

The OFDA / CRED International Disaster Database contains essential core data on the occurrence and effects of over 12,800 mass disasters in the world from 1900 to the present. This database is maintained by the Centre for Research on the Epidemiology of Disasters in Brussels (CRED) and can be accessed at www.cred.be. In this study floods which occurred between 1975 and 2002 are analysed. Information from the database considering date and location of the disaster and the numbers of killed and affected persons have been used. In total, records from 1903 flood events are analysed, although not all records have complete information.

The impacts of a flood will be strongly influenced by the characteristics of the inundated area and the characteristics of the flood itself. For example, rapidly rising flash floods can cause more devastation than small scale inundations due to drainage problems, and people in developing countries might be more vulnerable to the flood hazard than the inhabitants of industrialised regions. Area characteristics such as population density and magnitude, land use, warning- and emergency measures differ on a regional scale and will have a large influence on the loss of life caused by a flood. Information on the location of the flood events can be abstracted from the database. The hydraulic characteristics will depend on the type of flood. Four types of floods are distinguished in this study which all have a distinctly different flood profile:

- coastal flood (or storm surge): These occur along the coasts of seas and big lakes. Wind causes setup of water levels on the coast, leading to (extreme) high water levels and a flooding of the coastal area
- river flood: caused by flooding of the river outside it's regular boundaries. Can be accompanied by a breach of dikes or dams next to the river (when present). Flood can be caused by various sources: high precipitation levels, not necessarily in the flooded area, or other causes (melting snow, blockage of the flow)
- flash flood: these occur after local rainfall with a high intensity. This type is characterised by a quick raise of water levels causing a threat to lives of the inhabitants. Severe rainfall on the flooding location may be used as indicator for this type of flood. Generally occurs in mountainous areas. The US National Weather Service has defined flash floods as those that follow within a few hours of heavy or excessive rain, a dam or levee failure, or a sudden release impounded by an ice jam.
- drainage problems: caused by high precipitation levels that cannot be handled by regular drainage systems. This type of threat poses no (or a very limited) threat to life due to limited water levels and causes mainly economic damage.

[1] Derived from statistics from OFDA / CRED International Disaster Database, www.cred.be

The flood events in the database have been classified by flood type, using information from the underlying sources of the database, such as UN and Red Cross reports and newspaper articles.

1 Analysis of flood mortality by region

Flood mortality is defined as the fraction of the inhabitants of the flooded area that have lost their lives in the flood.

mortality = number of fatalities / total number of affected persons

Flood mortality is determined for the 17 regions defined in the CRED database. Figure shows average and standard deviation of flood mortality by region. The results show that mortality varies by region, but that the expectation that floods in areas with lower living standard will cause higher mortality cannot be supported. Mortality is for example relatively high for the European Union, while West Africa has a low average flood mortality.

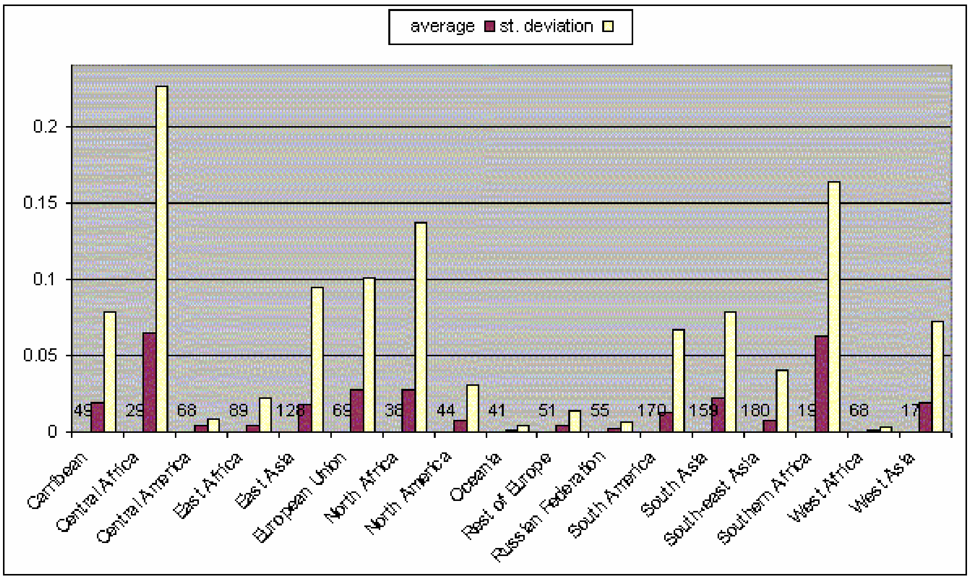


Figure 1 Mortality (average and standard deviation) by region, numbers at the bottom of graph indicate the number of classified events

Figure 2 indicates the magnitude of the flood events. The figure shows, for the flood events with more than 0 fatalities, the number of affected people on the x-axis and the number of killed on the y-axis. For the purpose of the regional analysis also the continents are shown in the figure, which is plotted on a double logarithmic scale.

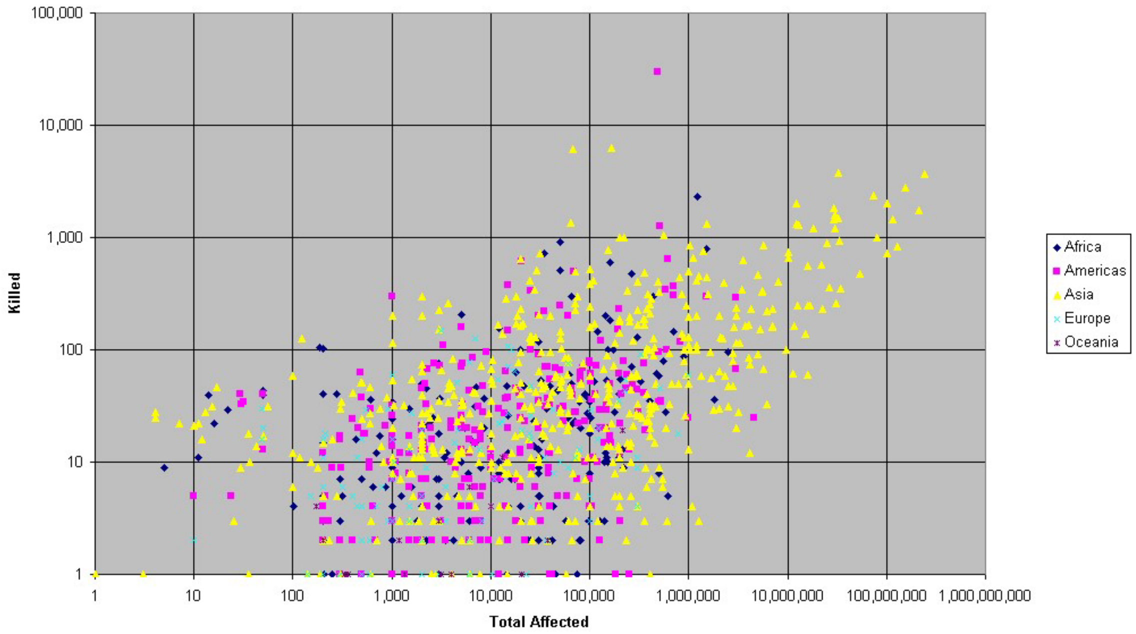


Figure 2 Number of fatalities and people affected for floods with more than 0 fatalities by continent

The figure shows that floods with a large number of affected people are mainly Asian floods: The first 45 floods with the highest number of people affected all occurred in China, India, Bangladesh or Pakistan. The event with most fatalities occurred in 1999 in Venezuela: about 30.000 people died during flash floods and extensive land and mudslides. Also most of the floods with more than 1000 fatalities occurred in Asia.

2 Analysis of flood mortality by flood type

714 flood events, for which a description of the event was available, have been classified by flood type. Figure 2 shows and average and standard deviation of mortality for the four defined flood types (coastal, flash and river flood and drainage problems).

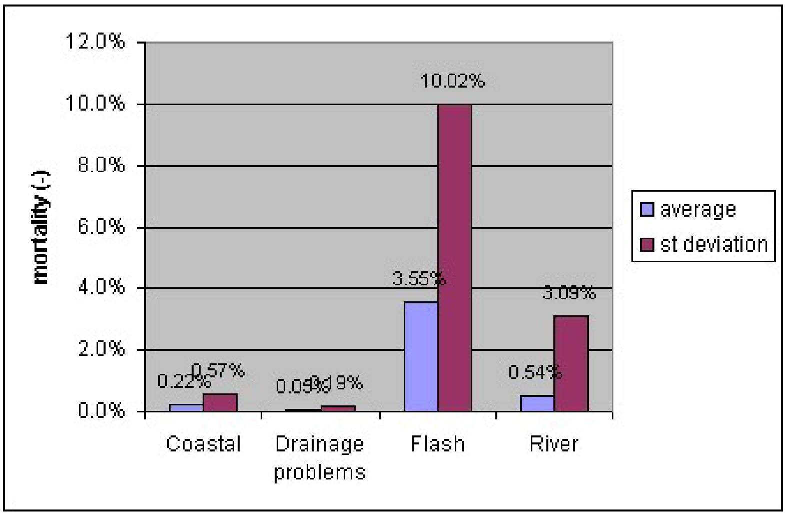


Figure 3 Mortality worldwide for different types of floods

The extent of the flood events is shown in figure 3, where the number of killed is shown as a function of the number of affected people for every flood event.

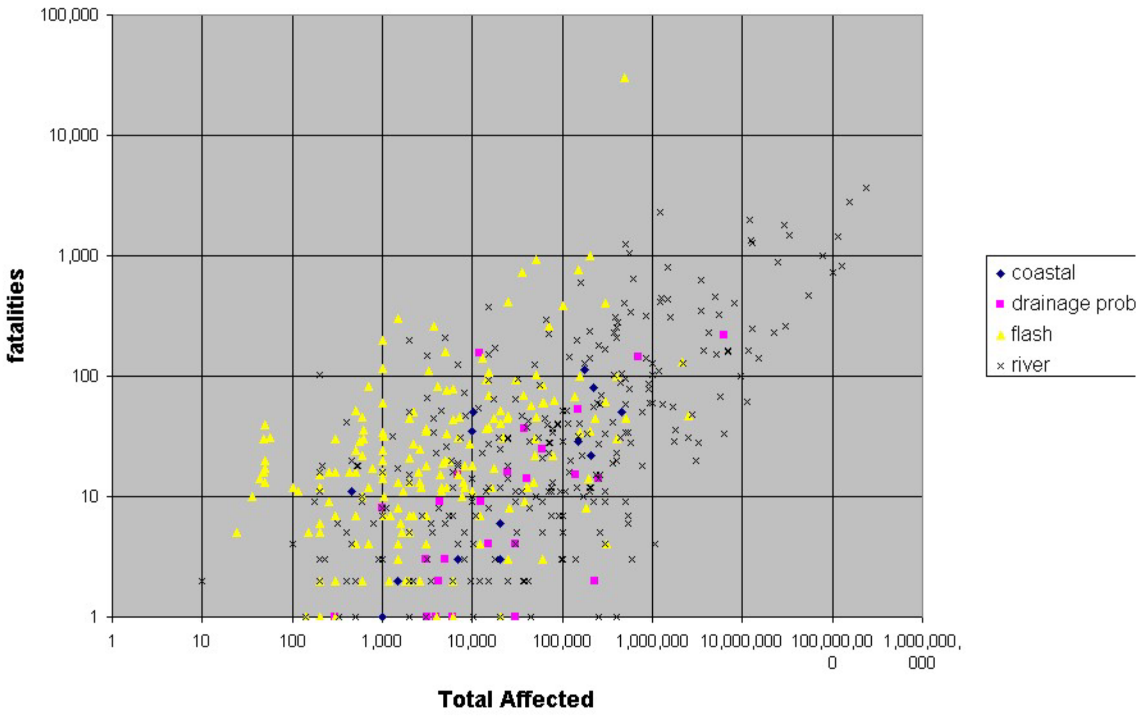


Figure 4 Number of fatalities and people affected for floods with more than 0 fatalities by flood type

These figures show that flash floods affect relatively little people but cause relatively high numbers of fatalities and result in high mortality. A review some individual flood events shows that especially flash floods accompanied by land- and mudslides are dangerous. Consider for example the 1999 Venezuela floods / mudslides resulting in 30,000 deaths. River floods result in higher numbers of affected, but relatively low mortality. In the case of drainage problems loss of life and mortality are small. A combined analysis by flood type and location shows that average mortality seems to be relatively constant for the different flood types over various regions.

3 Causes of flood deaths

While the previous analysis provides insight in magnitude of flood mortality, it does not indicate how people drown in floods. Therefore death statistics for some European river floods have been studied, for the 2002 Elbe river floods in Germany (27 killed), the 1997 river floods in Poland (55 killed) and the 2001 river floods in Poland (27 killed). Also the death caused for the 1953 coastal floods in the Netherlands (1835 killed) and the United Kingdom (313 killed) were investigated. Finally other available studies on Australian flood deaths (Coates, 1999) and United Sates flash flood fatalities (French, 1983) & (Mooney, 1983) were included.

A first classification of deaths caused by floods is proposed in table 1. A distinction is made between deaths due to direct contact with the floodwaters, and indirect death causes.

direct deaths
car related
drowning / swept in water
boating
performing / during rescue
trapped in building / collapse
indirect deaths
trauma
heart attack
electrocution
others / unkown

Table 1: Proposed classification on flood deaths

The contribution of these categories to death toll may depend on the flood characteristics (mainly determined by the type of flood), the local area characteristics, and the response of the persons to the flood exposure.

From the several sources of information on flood fatalities for several cases studies covering different types of floods (river, coastal, hurricane) no final conclusions on the relevance of certain death causes can be drawn yet. However some first patterns emerge from the limited data available from the various sources. The two studied coastal flood events occurred unexpectedly without pre-warning or evacuation. Most deaths occurred amongst persons trapped in buildings and in the rapidly flowing waters near the breaches.

For the studied river flood cases, the main death causes were persons drowning after being swept in the water and the car related accidents. A major percentage of deaths in European floods is believed to be connected to risk-taking behaviour. In (WHO, 2002) it is estimated that in European floods 40% of all health impacts to be related to risky behaviour. Several sources indicate the hazards associated with the rescue process, especially for voluntary rescuers. Also limited numbers of fatalities occurred due to indirect causes, such as shock, heart-attack and electrocution.

The available statistics on United States flash floods (French, 1983 & Mooney, 1983) show that almost half of the flash flood fatalities are car-related. For all flood types the young and elderly are more vulnerable in floods. Males are over-represented in the flood death statistics for river and flash floods. This could probably related to male risk-taking behaviour. Flood can also influence long term mortality. Increased stress levels after the flood, and more cases of diseases and illnesses may result in a rise of mortality in the months and years after the flood. For example, Bennet (1970) showed an increase in mortality in the period after the 1968 Bristol floods in the United Kingdom.

4 Concluding remarks

This study provides some insight in general mortality for worldwide floods. The results show that the mortality associated with a flood events will strongly depend on the flood characteristics, i.e. on the flood type. Also the way people respond to the exposures is a critical factor in the morbidity and mortality associated with such events (French, 1989).

For prevention of flood health effects more insight in the causes due to which flood deaths occur is necessary. Based on a limited number of case studies a first analysis of death causes is given. However, the empirical evidence for the relevance of the different death causes is rather weak. Also the knowledge on the non-lethal effects associated with floods is limited. Therefore there is a need for more and better quantitative data on health impacts associated with all categories of flooding. This includes centralized and systematic national reporting of deaths and injuries from floods using a standardized methodology (WHO, 2002).

The results of these studies may provide some insights in the potential magnitude of flood events and can aid the development of vulnerability indicators for flood hazards. Insights gained can provide background for decision making on the desired level of flood protection and the application of measures to prevent flood deaths.

5 References

Bennet, G.
Bristol floods 1968 – Controlled survey of effects on health of local community disaster
British Medical Journal, 3, 454-458, 1970.

Berz G., Kron W., Loster T., Rauch E., Schimetschek J., Schmieder J., Siebert A., Smolka A., Wirtz A.
World map of natural hazards – a global view of the distribution and intensity of significant exposures
Natural Hazards 23, p.443 – 465, 2001

Coates L.
Flood fatalities in Australia, 1788 – 1996
Australian Geographer, Vol. 30, No. 3, p. 391 – 408, 1999

French J., Ing. R. , von Allmen S., Wood R.,
Mortality from flash floods: a review of the national weather service reports, 1969 – 1981
Public Health Rep. 98 (6): 584 – 588, 1983

French JG, Holt KW.
Floods
In: *Gregg MB, ed. The public health consequences of disasters. Atlanta, Georgia: US Department of Health and Human Services, Public Health Ser-vice, CDC*, 1989:69–78.

Mooney L.E.
Applications and implications of fatality statistics to the flash flood problems
in: *Proceedings of the 5th conference on hydrometeorology*, Tulsa USA, 1983

World Health Organization – regional office for Europe
Floods: climate change and adaptation strategies for human health
2002

General Appendix: Delft Cluster Research Programme Information

This publication is a result of the Delft Cluster research-program 1999-2002 (ICES-KIS-II), that consists of 7 research themes:
►Soil and structures, ►Risks due to flooding, ►Coast and river , ►Urban infrastructure, ►Subsurface management, ►Integrated water resources management, ►Knowledge management.

This publication is part of:

Research Theme	:	Risk of Flooding		
Baseproject name	:	Consequences of floods		
Project name	:	Consequences of floods		
Projectleader/Institute		Prof. A.C.W.M. Vrouwenvelder		TNO
Project number	:	02.03.03		
Projectduration	:	01-04-2002	-	1-07-2003
Financial sponsor(s)	:	Delft Cluster		
		Ministry of Public Works, Road and Water Management		
Projectparticipants	:	GeoDelft		
		WL|Delft Hydraulics		
		TNO		
		Delft University of Technology		
		Twente University		
		Alterra		
		CSO		
		Delphiro		
Total Project-budget	:	€ 450.000		
Number of involved PhD-students	:	2		
Number of involved PostDocs	:	0		

Delft Cluster is an open knowledge network of five Delft-based institutes for long-term fundamental strategic research focussed on the sustainable development of densely populated delta areas.

Keverling Buismanweg 4
Postbus 69
2600 AB Delft
The Netherlands

Tel: +31-15-269 37 93
Fax: +31-15-269 37 99
info@delftcluster.nl
www.delftcluster.nl

Theme Managementteam: Ground and Construction

Name	**Organisation**
Prof. J.K. Vrijling	Delft University of Technology
Ir. E.O.F. Calle	GeoDelft
Prof. A.C.W.M. Vrouwenvelder	TNO

Projectgroup

During the execution of the project the researchteam included:

Name	**Organisation**
Prof. Ir. A.C.W.M. Vrouwenvelder	TNO
Dr. Ir. P.H. Waarts	TNO
Ir. J.E.A. Reinders	TNO
Dr. E.E. van der Hoek	GeoDelft
Ir. S.N. Jonkman	RWS-DWW
Ir. K. Heynert	WL | Delft Hydraulics
Prof. A. van der Veen	Twente University
Ir. L.C.P.M. Stuyt	Alterra
Ir. M. de Muinck Keizer	Delphiro/CSO

Other Involved personnel

The realisation of this report involved:

Name	**Organisation**
Ir S.N. Jonkman	RWS-DWW

Annex A: Health effects of floods

1 Introduction

Within the context of a Dutch research project, which aims at assessing the various types of flood damage (to economy, ecology, etc.), this annex reviews some of the information available in literature on the health effects of floods. The World Health Organisation (1948) defines health as “a state of complete physical, social and mental well-being, and not merely the absence of disease and infirmity”. Health effects of floods can thus be considered as those effects of floods, which lead to a decrease of physical, social and mental well-being.

Aim of the investigation is to give an overview of the various types of health effects and to add information reported health effects from past floods to these descriptions. The study focuses especially on quantitative data to get an impression of the extent of the reported health effects. These results can provide a further basis for prevention strategies and the quantitative estimation of health effects caused by floods. This study will describe both the non-lethal health effects of floods, and loss of life.

Much has been published on health effects of (natural) disasters. This literature study is limited to publications which describe flooding health effects, with special interest for documents which describe health effects observed during or after floods in the past. Main sources of literature consulted were publicly available sources such as British Medical Journal[1] and CDC’s Morbidity and Mortality Weekly Report[2]. The author realizes that the overview of cases is far from complete. All those who are interested are invited to comment and share information on health effects from flooding cases.

The document is structured as follows: A classification of health effects is discussed in section 2. Based on a review of the existing literature health effects caused by floods in the past are described in sections 3 (physical health effects) and 4 (psychological health effects). Fatalities caused by floods are discussed in section 5. Conclusions are summarized in section 6.

2 Classification of flooding health effects

Following previously proposed classifications (see for example (Menne, 1999), (WHO, 2002)) the health effects of floods can be categorized into direct effects caused by floodwaters, and indirect effects caused by other systems damaged by the flood. An overview of direct and indirect health effects is given in table 1.

---

[1] Bristish Medical Journal: www.bmj.org
[2] CDC’s Morbidity and Mortality Weekly Report: http://www.cdc.gov/mmwr/

Table 1: Proposed classification of direct and indirect health effects of floods (WHO, 2002)

Direct effects

Causes	Health implications
Stream flow velocity; topographic land features; absence of warning; rapid speed of flood onset; deep floodwaters; landslides; risk behaviour; fast flowing waters carrying boulders and fallen trees	Drowning Injuries
Contact with water	Respiratory diseases; shock; hypothermia; cardiac arrest
Contact with polluted waters	Wound infections; dermatitis; conjunctivitis; gastrointestinal illnesses; ear, nose and throat infections; possible serious waterborne diseases
Increase of physical and emotional stress	Increase of susceptibility to psychosocial disturbances and cardiovascular incidents

Indirect effects

Causes	Health implications
Damage to water supply systems; sewage and sewage disposal damage; Insufficient supply of drinking water; Insufficient water supply for washing	Possible waterborne infections (enterogenic E. coli, Shigella, hepatitis A, leptospirosis, giardiasis, campylobacteriosis); dermatitis and conjunctivitis
Disruption of transport systems	Food shortage; disruption of emergency response
Underground pipe disruption; dislodgment of storage tanks; overflow of toxic-waste sites; release of chemicals; disrupture of gasoline storage tanks may lead to fires	Potential acute or chronic effects of chemical pollution
Standing waters; heavy rainfalls; expanded range of vector habitats	Vector borne diseases
Rodent migration	Possible diseases caused by rodents
Disruption of social networks; loss of property, jobs and family members and friends	Possible psychosocial disturbances
Clean-up activities following floods	Electrocutions; injuries; lacerations; skin punctures
Destruction of primary food products	Food shortage
Damage to health services; disruption of "normal" health service activities	Decrease of "normal" health care services, insufficient access to medical care

Source: MENNE ET AL. *Floods and public health consequences, prevention and control measures.* UN, 2000 (MP.WAT/SEM.2/1999/22)

The table shows the relevance of health effects caused by the chain reactions associated with flooding, such as the release of chemicals or the damage to water supplies. Another possible classification considers the moment of occurrence of the health effects: directly during the flood, in the days or weeks after the flood and the long-term effects after months or even years. In the following sections a somewhat different classification is adopted. A distinction is made between physical effects of floods and the psychological health effects. These can, sometimes indirectly, lead to loss of life, as is schematically shown in figure 1. Certain physical health effects, such as hypothermia or severe injuries can eventually lead to death. Psychological health effects, for example increase stress levels can influence long-term mortality. Also the relation between physical and psychological well being needs to be considered.

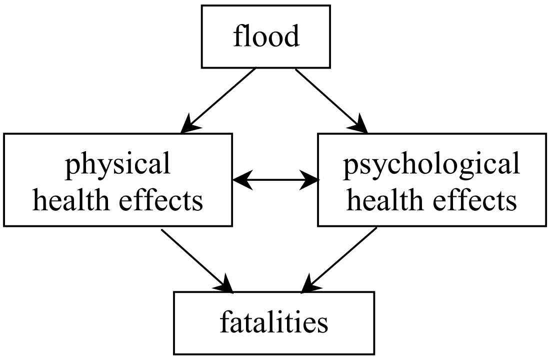


Figure 1: Relations between different types of health effects of floods

In the figure only direct effects of the flood are schematised. Also the health effects associated with chain reactions need to be considered, for example the health effects caused by toxic materials released from chemical plants damaged by the floods.

3 Physical health effects

In this section the non-lethal physical health effects due to direct and indirect contact with the water (section 3.1), the possible outbreak of diseases and illnesses (section 3.2), the potential toxic effects of released chemicals (section 3.3) and the consequences for public health services (section 3.4) are discussed.

3.1 Physical effects due to direct and indirect contact with the water

During the flood direct contact with the water and floating debris can lead to injuries, such as cuts and sprains. Especially rapidly flowing water carrying debris can lead to injuries. Also indirect causes, such as the collapse of buildings due to floodwaters can result in physical effects. When persons are in the water for a longer period aspiration of water, hypothermia and cardiovascular changes can occur, which can eventually lead to death (Bierens, 1996). In the period after the flood injuries can occur during the clean up phase; Especially cases of electrocution and carbon monoxide poisoning are repeatedly reported.

Observed physical health effects

French & Holt (1989) summarized several studies on the long term health effects from floods. Flood victims of the 1972 tropical storm Agnes showed more cases of hypertension. Similar findings were given for the population affected by the 1964 floods in Voroshiilovgrad and the 1969 floods in Tiraspol, Moldavia. A study after the flooding of the Amur river (Russia) in 1951-1952 showed increased blood pressure for almost the whole the population in the flooded area, and increases in blood pressure for 20-22% of the non-flooded families.

On October 3 1988 parts of the city of Nimes (France) and it's surroundings were flooded. The homes of about 45.000 persons were damaged. An assessment of the health effects showed only three severe injuries directly due to the flood (one with burns, two with fractures). Furthermore two cases of hypothermia, three instances of near drowning and ten minor injuries occured. Community survey amongst 228 persons revealed that 6% of all persons reported mild injuries (contusions, cuts and sprains), of which 70% were sustained during the impact phase/ In 66% of these cases medical care was obtained from a health care facility or a member of the family. After the floods twelve cases of carbon monoxide poisoning and a few sprains were reported among rescue and clean up workers (Duclos, 1991).

After the Mississippi and Missouri river floods in 1993, which affected 60.000 persons, a survey was conducted on health effects (MMWR, 1993a). During July 16–September 3, 524 flood-related conditions were reported. Of these, 250 (47.7%) were injuries, 233 (44.5%) were illnesses (see section 3.2), 39 (7.4%) were listed as “other,” and two (0.4%) were listed as “unknown.” Of the 250 reported injuries, the most common were sprains/strains (86: 34%), lacerations (61: 24%), “other injuries” (28: 11%), and abrasions/contusions (27: 11%).

After the Iowa 1993 flood (MMWR, 1993b) seven counties (14% of the population) reported persons hospitalised for: carbon monoxide poisoning (related to the indoor use of gasoline-powered generators), hypothermia, electrocution and wound infections.

A study by Daley et al. (2001) describes a documented outbreak of CO poisoning associated with flooding in 1997 in Grand Forks, North Dakota in the United States. Thirty-three laboratory-confirmed cases were identified, involving 18 separate incidents. Patients ranged in age from 7 to 67 years, and most of them were men. One patient lost consciousness and was admitted to the hospital; all others were released after receiving supplemental oxygen. Every incident involved gasoline-powered pressure washers being used in basements.

After the Hurricane Floyd in 1999, which caused flooding in the Eastern part of the United States, epidemiological information was evaluated (MMWR, 2000). 59.398 emergency department visits were reported in the period Sept 16 – Oct 27 after the floods. 28% of these visits were due to orthopedic and soft tissue injury, and 5% for other injuries. 19 cases of hypothermia (including one death) and 10 cases of carbon monoxide poisoning occurred following the hurricane, while no hypothermia and carbon monoxide poisoning cases were reported during the 1998 reference period. A comparison of medical data for the period after the Hurricane with those of the year before the flood, showed significant increases in dog bites were reported in the week after the floods.

A survey conducted on the health effects after floods in the UK in 1998 and 2000 revealed the following effects during or immediately after the floods (Baxter, 2001): injuries from over-exertion during the flood (e.g. sprains), hypothermia, cold, coughs, flu, headaches, sore throats or throat infections, skin irritations e.g. rashes, shock. In the weeks or months after the floods the following health effects were reported: Cardiac problems, Respiratory problems (e.g. asthma, chest infections, pleurisy), Lacerations, abrasions and contusions, Sprains and strains, Skin irritations (e.g. rashes, dermatitis etc.), High blood pressure, Kidney or other infections, Stiffness in joints, Muscle cramps, Insect or animal bites, Erratic blood sugar levels (diabetics), Weight loss or gain, Allergies (e.g. to mould spores).

3.2 Outbreak of diseases and illnesses

Direct contact with polluted water can lead to wound infections, dermatitis, conjunctivitis, gastrointestinal illnesses, ear- ,nose- and throat infections. After a flood there is a possibility of the outbreak of diseases and illnesses due to different causes. Animal diseases can be transferred to humans via contact with water (WHO, 2002). In addition, flooding can result in vector-associated problems, including increases in mosquito populations that, under certain circumstances, increase the risk for some mosquito borne infectious diseases (e.g., viral encephalitis) (MMWR, 1993b). Increased rates of diarrhoea (including cholera and dysentery), respiratory infections, hepatitis A and E, typhoid fever, leptospirosis, and diseases borne by insects can occur after floods in developing areas (Ohl, 2000). Diseases can be spread due to the pollution and disrupture of drink water and the sewage system. Water sources can become contaminated with faecal material or toxic chemicals (see 3.3), and solid-waste collection and disposal can be disrupted. On the longer term increases in malignant diseases (e.g. cancer) in the flooded area are reported, which may be explained by the increased stress levels (see section 4 on psychological effects).

Observed health effects

French & Holt (1989) summarize several studies on illnesses and diseases after floods. Flood victims of the 1972 tropical storm Agnes did not report more illnesses, but a longer duration of the illnesses. They also report several cases of outbreaks of infectious diseases. An outbreak of leptospirosis (107 cases) occurred after floods in July in 1975 in Brazil. An increase in Malaria was reported in Haiti after floods in 1963. After the 1969 floods in Moldavia increased numbers of cases of scarlet fever (doubled) and whooping cough (tripled) and the outbreak of dysentery were reported. After floods in 1979 in the Dominican Republic more cases of typhoid, paratyphoid, hepatitis and measles occurred. A study on lymphoma and leukaemia in the Canisteo River Valley after floods in 1972 showed an increase of these disease rates of 35% in the period of 1974-1977 (also a small increase in the non flooded towns was observed). Also a significant excess of spontaneous abortions in the year after the flood (1973) was observed. It was stated that these reported morbidity problems (hypertension, cardiovascular disease – leukaemia and lymphoma) may be stress related.

After the Iowa flood in July 1993 (MMWR, 1993b) which affected 99 counties the following was reported. Des Moines, in Polk County, was the only community without an operating public water system; the loss of this system affected more than 250,000 persons (9% of the population). Ten counties (15% of the population) reported at least one non-operational public sewer system, and 45 counties (53% of the population) reported vector problems. No out-breaks of diarrhoeal disease or waterborne diseases were identified. Twelve of 99 counties (12% of the population) reported problems with solid-waste disposal; 35 counties (33% of the population) reported increased complaints about mosquitoes and rats.

After the Mississippi and Missouri 1993 floods (also see section 3.1) 233 illnesses were reported. Of the 233 reported illnesses, the most frequently reported were gastrointestinal (40:17%), rashes/ dermatitis (38: 16%), heat-related (31: 13%), and “other conditions” (47: 20%) (MMWR, 1993b).

In Poland and outbreak of leptospirosis occurred following the 1997 Odra floods. There was an increase in cases of leptospirosis in the Czech Republic after the 1997 floods (McCarthy, 2001) and (http://www.who.dk/ccashh/Extreme/20020610_1). After the monsoon floods in 1999 in the Philippines the number of cases of leptospirosis has been reported to be three times the usual number (Easton A., 1999).

A “marked increase” of diarrhoea among children, and numerous cases of cholera and the outbreak of malaria were reported after the 1998 floods in Somalia. Also up to 50 people died due an outbreak of possibly anthrax, caused by the drinking of contaminated water (Climent, 1998)

After the flood in August 1998 a disease surveillance system was established in Khartoum Sudan to assess the health status of the affected population. No outbreaks of typhoid, cholera or measles were confirmed. Diarrhoea was the most common cause if morbidity, accounting for 31% of the 29.526 reported visits. Research showed under-nourishment of children (MMWR, 1989). However, results from this study are difficult to interpret since no prior flood information is given.

After the Hurricane Floyd in 1999, which caused flooding, epidemiological information was evaluated. 59.398 emergency department visits were reported in the period Sept 16 – Oct 27 after the floods. Respiratory illnesses accounted for 15% of all visits, gastrointestinal illness for 11% and cardiovascular disease for 9%, and other illnesses for 33% of the cases. Routine surveillance by local public health workers identified outbreaks in shelters of self-limiting gastrointestinal disease band respiratory disease. Medical data for the period after the Hurricane were compared with data for the year before the flood. Significant increases in febrile illnesses and dermatitis were reported in the week after the floods, and significant increases in diarrhoea and asthma in the month after the flood. (MMWR, 2000)

3.3 Toxic effects

A special category of effects is related to the release of hazardous materials during the flood. Causes can be the disruption of under ground pipes, the dislodgment of storage tanks, the overflow of toxic-waste sites and the release of chemicals from damaged installations. Direct effects to human health can occur due to contact with the chemicals. Secondary effects can occur when substances react or when fires or explosions occur. Disrupture of gasoline storage tanks may for example lead to fires. On the longer term flood water can pollute the inundated land and harm agriculture and the animal and fish population. Toxic materials can enter the food chain (for example in rice or fish) and therefore indirectly lead to human health effects.

Observed toxic health effects
An overview of toxic effects due to release of chemicals after some floods is given by French & Holt, but “information on adverse health effects associated with such exposures is limited”. After the release of pesticides in the Snake river after floods in 1976 high levels of DDT and PCB were reported in the fish population. A broken pipe at a fertilizer plant in Vila Parisi, Brazil in 1985 led to the release of ammonia causing treatment of 63 persons.
During the clean up after the 1988 Nimes flash floods three instances of exposure to chlorinated derivatives were reported (Duclos, 1991).

3.4 Disruption of public health services

An aspect closely related to the physical health effects is the functioning of the public health services before, during and after the flood. The flood related activities of public health services in these phases can be summarized as follows (partly based on experiences from the 1953 disaster from the Netherlands (Baxter, 2001):
Before the flood:
- evacuation sick and old, hospitals,
- treatment of effects of evacuation (stress from being displaced, heart attacks)

during or shortly after disaster:
- providing first aid, treatment of injuries
- identifying and recovering corpses;

After:
- restoring hygienic services (food, water, sanitation)
- providing physicians with routine supplies
- taking measures to fight epidemics.
- epidemiological assessment of health effects caused by flooding
- increased demand for medical services due to long term effects of floods (decrease of physical and mental well-being)

Observations from flood cases
After the Bristol 1968 floods hospital referrals and admissions more than doubled compared with those in the year before the flood (Bennet, 1970)

After the flash floods in Nimes in 1988, only 2% of the interviewed persons who had routinely scheduled medical treatments or drug prescriptions reported that they had experienced problems (Duclos, 1991).

Following the July 1993 Iowa floods the following was reported (MMWR, 1993b): Five of the 99 counties, representing 14% of Iowa’s population, reported closures of primary-care physician offices. Closures per county ranged from one office in Van Buren County (1990 population: 7676) to approximately 200 offices in Polk County (1990 population: 324,140). Eight counties (24% of the state population) reported interruptions in public health services (e.g., vaccination clinics, special supplemental food program for women, infants, and children, and sexually transmitted diseases clinics). Every county had at least one operating pharmacy. A survey was conducted on the availability of medical services. The number of counties reporting limitations in availability of medical or public health services decreased from eight (24% of the population) during the July 15–16 assessment to four (3% of the population) in the week of July 18–24.

A difficult problem is the evacuation of flood threatened hospitals. Evacuation of some patients during the Dresden 2002 floods was considered too risky due to low immune defence capabilities (Tuffs, 2002).

4 Psychological health effects

Those directly affected by floods are likely to show an increase of physical and emotional stress, and an increase of susceptibility to psychosocial disturbances and cardiovascular incidents in the period after the flood. Also indirect effects can influence psychological well-being, for example the disruption of social networks and the loss of property and jobs.

As general psychological effects emotional trauma, stress, cases of depression and isolation a decrease of self-identity, behavioural changes, and even cases of posttraumatic stress are reported by (Ohl, 2000). Even a preventive evacuation without the occurrence of a flood can lead to psychological health effects, as can false rumours of the possibility of outbreak of infectious diseases can result in raised public concern (Ohl, 2000). There are differences in the way men and women cope with the disaster. Baxter (2001) reports based on qualitative studies that women's health in the majority of households was said to be most affected. The psychological health effects can be longer lasting for months or even years and are therefore a significant long-term effect of the flood.

Observed health effects

French & Holt (1989) summarized several studies on the long term health effects from floods. Psychiatric examinations performed on 224 children, 2 years after the 1972 flood in Buffalo Creek, West Virginia, showed that 80% of children were severely emotionally impaired by their experiences during and after the flood (original refs given in (French, 1989)). Flood victims of the 1972 tropical storm Agnes showed more cases of hypertension and more stress cases.

Also the study following the 1968 Bristol floods by (Bennet, 1970) showed an increase of psychiatric symptoms, which are assumed to have lead to an increase of mortality (see section 5).

Nimes physicians reported an increase in visits for mental problems after the 1988 floods. From a community survey amongst 228 persons, 19% of the persons mentioned stress related problems after the flood, such as insomnia or anxiety. (Duclos, 1991)

After the Iowa 1993 floods (MMWR, 1993b) two of the 99 affected counties (2% of the population) reported increases in admissions to substance-abuse programs, and nine counties (16% of the population) reported increases in admissions to mental health facilities.

Medical data for the period after the Hurricane Floyd in 1999 were compared with data for the year before the flood. Significant increases in suicide attempts were reported in the week after the floods, and significant increase in violence (i.e. assault, gunshot, wounds and rape) one month after the flood (MMWR, 2000).

After the 1998 and 2000 floods in the UK the following psychological health effects were reported (Baxter, 2001):

- Anxiety e.g. during heavy rainfall
- Panic attacks
- Increased stress levels
- Mild, moderate, and severe depression
- Lethargy/lack of energy
- Feelings of isolation
- Sleeping problems
- Nightmares
- Flashbacks to flood
- Increased use of alcohol or prescription (or other) drugs
- Anger/tantrums
- Mood swings/bad moods
- Increased tensions in relationships e.g. more arguing

- Difficulty concentrating on everyday tasks
- Thoughts of suïcide

Quantitative research after the UK floods showed that flood victims frequently report to feel depressed and isolated (Baxter, 2001) based on (Tapsell, 2000).

5 Fatalities caused by floods

In this section the mortality associated with floods is approached as a separate health effect. However, it has to be stressed that the injury, illness, disease and psychological stress can lead to death (as is also shown in figure 1). Section 5.1 discusses statistics on mortality for worldwide flood events. The causes of flood deaths are described in section 5.2, observations from case studies are summarized in section 5.3.

5.1 Mortality statistics for worldwide floods

A study has been carried out to investigate loss of life statistics for different types of floods and different regions, results are more extensively reported in (Jonkman, 2002a), this section contains a summary of the findings.

General information from the CRED disaster database concerning a large number of worldwide flood events has been analysed. The OFDA / CRED International Disaster Database contains essential core data on the occurrence and effects of over 12,800 mass disasters in the world from 1900 to the present. This database is maintained by the Centre for Research on the Epidemiology of Disasters in Brussels (CRED) and can be accessed at www.cred.be. In this study floods which occurred between 1975 and 2002 are analysed. Information from the database considering date and location of the disaster and the numbers of killed and affected persons have been used. In total, records from 1903 flood events are analysed, although not all records have complete information.

The impacts of a flood will be strongly influenced by the characteristics of the inundated area and the characteristics of the flood itself. For example, rapidly rising flash floods can cause more devastation than small-scale inundations due to drainage problems, and people in developing countries might be more vulnerable to the flood hazard than the inhabitants of industrialised regions. Area characteristics such as population density and magnitude, land use, warning- and emergency measures differ on a regional scale and will have a large influence on the loss of life caused by a flood. Information on the location of the flood events can be abstracted from the database. The hydraulic characteristics will depend on the type of flood. Four types of floods are distinguished in this study which all have a distinctly different flood profile: coastal flood, river flood, flash flood and drainage problems. The flood events in the database have been classified by flood type, using information from the underlying sources of the database, such as UN and Red Cross reports and newspaper articles.

Analysis of flood mortality by region

Flood mortality is defined as the fraction of the inhabitants of the flooded area that have lost their lives in the flood. *mortality = number of fatalities / total number of affected*

The analysis shows that flood mortality averaged over the flood events is constant for the different continents (Asia, Africa, Americas, Europe, Oceania). A similar analysis is also made on the regional level, for the 17 regions as defined in the CRED database. The results (see appendix A) show that mortality varies by region, but that the expectation that floods in areas with lower living standard will cause higher mortality cannot be supported. Mortality is for example relatively high for the European Union, while West Africa has a low average flood mortality.

Analysis of flood mortality by flood type

In figure 2 mortalities are shown for the different defined flood types (coastal, flash and river flood and drainage problems), for 714 flood events classified by flood type.

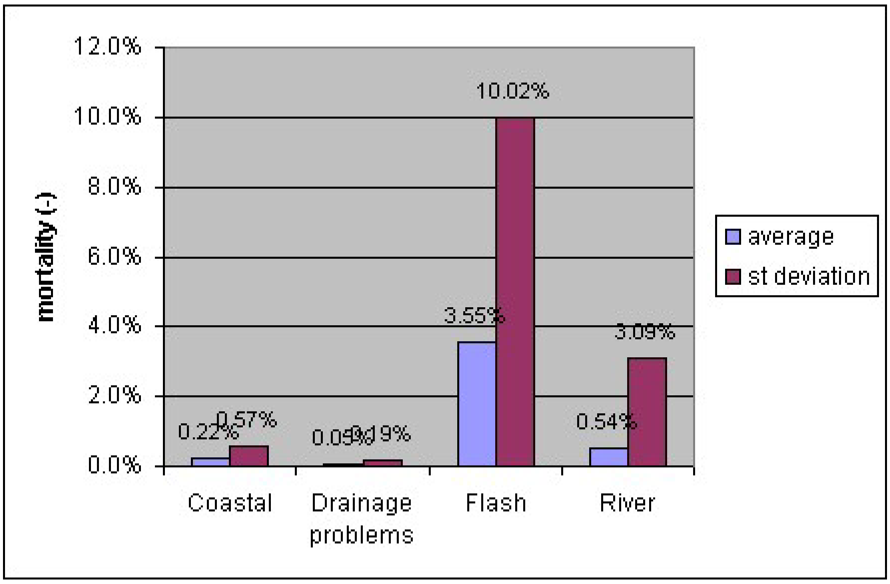


Figure 2: Mortality worldwide for different types of floods

The extent of the flood events is shown in figure 3, where the number of killed is shown as a function of the number of affected people for every flood event, more statistics on the different types of flood events are found in appendix B.

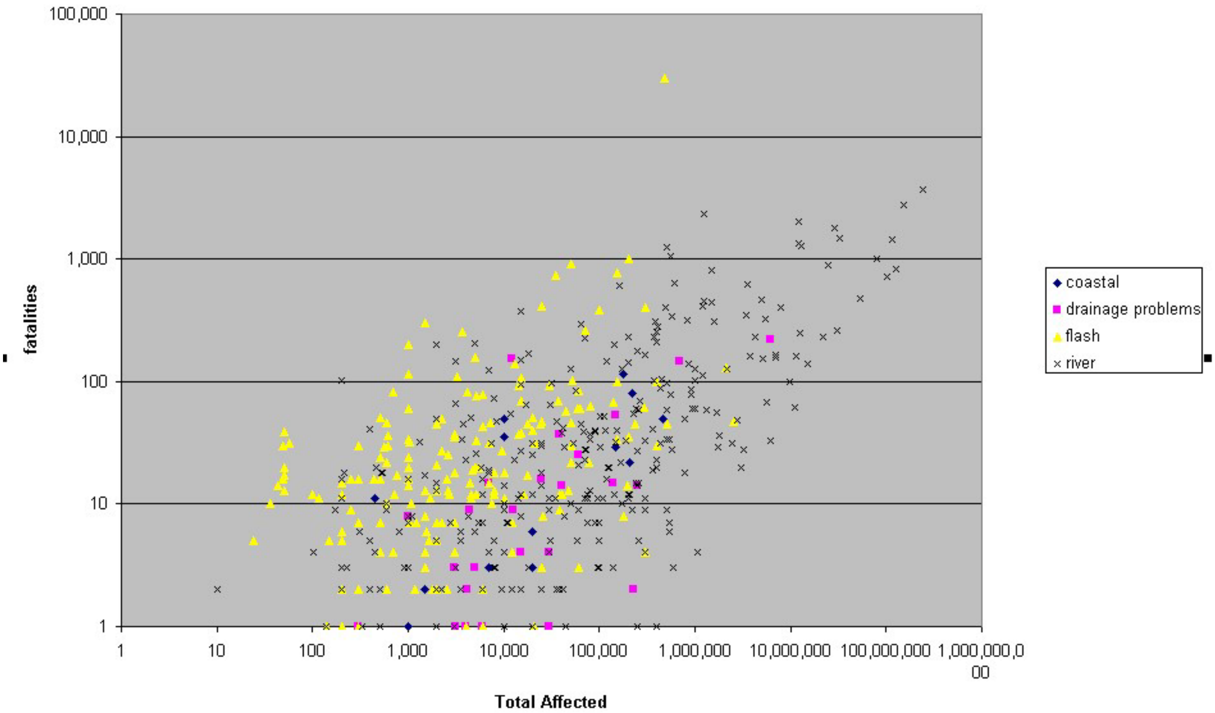


Figure 3: Number of fatalities and people affected for floods with more than 0 fatalities by flood type

These figures shows that flash floods affect relatively little people but cause relatively high numbers of fatalities and result in high mortality. A review some individual flood events shows that especially flash floods accompanied by land- and mudslides are dangerous. Consider for example the 1999 Venezuela floods / mudslides resulting in 30,000 deaths. River floods result in higher numbers of affected, but relatively low mortality. In the case of drainage problems even more people are affected, but loss of life and mortality are small. A combined analysis by flood type and location shows that average mortality seems to be relatively constant for the different flood types over various regions. The results of this study provide some insight in general mortality for worldwide floods. For prevention of flood health effects more insight in the causes due to which flood deaths occur is necessary.

5.2 Causes of flood deaths

More insight in the causes of death for different flood types and the contribution of the causes to the death toll is necessary. These insights will provide a basis for preventive measures. Knowledge obtained can also form the basis for the development of methods for estimation of flood mortality, see (Jonkman, 2002b) for an overview.

An inundation may claim lives during and shortly after the flood, and can also cause influence long term mortality.

Fatalities during the flood period

During the flood period death will occur when are swept into the water. This danger is most present in rapidly flowing waters. However, tests carried out by Abt et al. (1992) on the stability of persons in flowing water, showed that persons will lose their stability in very limited water depths and flow velocities. The young and elderly will be more vulnerable to lose their stability. An additional danger is the debris carried by the waters. People being swept in the water by flood waters will in many cases eventually drown. A detailed description of the drowning process is given by Bierens (1996): aspiration of water, hypothermia and cardiovascular changes can occur, which eventually lead to death.

Another major cause of deaths are the vehicle related accidents. Data from the Unites States shows that car related accidents are reported to be a major source of US flood deaths (French, 1983), see next section for a more detailed discussion. Cars can flow away in a few feet of water. Once floating the water pressure will prevent the opening of car doors.

Another dangerous activity is boating during the flood. Boats can easily collapse in flowing water. There are even some reports of persons canoeing in flooded areas for recreational purposes.

Building related deaths can occur in different ways. When the water levels rise very rapidly persons might be trapped at the lower floors or may not be able to reach higher levels of their home. Eventually flood water levels can even exceed the highest flood of the house. Another possibility is the collapse of buildings due to flood conditions. Fastly flowing water can lead to the collapse of walls and windows, as can other failure mechanisms such as collapse due to wave attack. Models for estimation of the collapse of buildings in floods are developed by Kelman (2002) and Roos (2003). The type of building is an important factor. After collapse of the building the inhabitants will have little changes of surviving.

Rescuers will have to operate in difficult conditions during a flood. In many cases rescuers have been reported to become a victim themselves. Especially the rescue of persons in swift-water introduces specific hazards for the rescuer (www.cfspress.com)

During and after flood electrocution can occur when people make contact with power supplies. Especially during the clean up phase the risk of electrocution is present.

The shock of seeing one’s home flooded can be too much for some. In multiple occasions deaths due to heart attacks and shock are reported during the flood. Even the mere stress of evacuation, without any contact with flood waters can lead to death. Elderly are more vulnerable in these conditions.

The conditions accompanying the floods can also lead to additional deaths. Bad weather and storms can cause additional deaths in traffic, due to more collisions and falling trees.

Based on the observations above the following classification for deaths caused for floods is proposed in table 2. A distinction is made between deaths due to direct contact with the floodwaters, and indirect death causes.

Table 2: Proposed classification on flood deaths

direct deaths
car related
drowning / swept in water
boating
performing / during rescue
trapped in building / collapse
indirect deaths
trauma
heart attack
electrocution
others / unkown

The health effects and mortality caused by floods are not only determined by the flood characteristics. The way people respond to exposures is a critical factor in the morbidity and mortality associated with such events (French, 1989). It is estimated that in European floods 40% of all health impacts to be related to risky behaviour. (WHO, 2002). Similar observations of deaths due to risk taking behaviour are given in (Jonkman, 2002a) and Coates (1999).

Flood can also influence long term mortality. Increased stress levels after the flood, and more cases of diseases and illnesses (see sections 3 and 4) may result in a rise of mortality in the months and years after the flood.

5.3 Analysis of deaths for flood cases

In order to compare the general descriptions of death causes with data from past floods, some data from flood cases have been collected. So far data from the following cases has been analysed:

- River Floods of the Elbe in Germany in 2002
- River floods in the Odra and Wisla rivers in Poland in 1997 and 2001
- Hurricane Floyd 1999, United States
- Coastal floods in 1953 in the United Kingdom
- Coastal floods in the Netherlands in 1953

Furthermore some available studies on flood mortality in the United States and Australia are briefly outlined.

A summary of data obtained on numbers of drownings and the different causes of death is given in table 3, the sources are listed separately in the references section. The first part of the table contains general information on the flood event (location, year, period, extent). The second part analysis death causes for those fatalities for whom this kind of data could be obtained.

Table 3: Causes of death for flood cases (total numbers of killed and affected derived from CRED database)

Flood	Germany 2002		Poland 1997		Poland Wisla 2001		US 1999		Netherlands 1953		UK 1953	
type	river		river		river		hurricane Floyd		coastal		coastal	
Year / period	aug-02		July 1997		July 2001		sep-99		febr 1 1953		febr 1 1953	
Affected area	Elbe / Dresden		Odra, Wisla		Wisla		East Coast		Southwest NL (Zeeland)		East Coast	
Total affected	330000		62000		15000		264000				32000	
Total killed	27		55		27		77		1835		313	
Anslysis of death causes												
Cause												
direct deaths	number	%	number	%	number	%	number	%			number	%
car related	1	4%	1	3%	4	27%	32	57%	other		4	1%
drowning / swept in water	5	20%	7	24%	9	60%	15	27%	classification		80	26%
boating	2	8%	2	7%	0	0%	7	13%	see table 4		0	0%
performing / during rescue	2	8%	1	3%	0	0%	0	0%			2	1%
trapped in building / collapse	1	4%	1	3%	2	13%	2	4%			183	58%
indirect deaths												
trauma	1	4%	1	3%	0	0%	only direct				16	5%
heart attack	4	16%	0	0%	0	0%	deaths given				7	2%
electrocution	0	0%	0	0%	0	0%					0	0%
others / unkown	9	36%	1	3%	0	0%					21	7%
Total	25		14		15		56				313	

Since the original data from the 1953 flood, given by (Waarts, 1992), in the Netherlands could not be classified following the proposed classification, an alternative classification is given in table 4, for the two coastal flood events.

Table 4: Causes of death of coastal floods in 1953 in the Netherlands and UK

	Netherlands 1953		**UK 1953**	
Causes	coastal		coastal	
rapidly rising water	1045	57%	173	55%
high flow velocities	254	14%	74	24%
other causes	427	23%	66	21%
unknown	69	4%	0	0%
died later by hardships and illness	40	2%	?	?
Total	1835		313	

The total number of fatalities is limited for the river floods. In these cases the floods could be predicted in advance and preventive evacuation could be set up. Much higher death tolls are found for the two coastal floods. These occurred unexpectedly at night, no evacuation could be carried out in advance.

A first interpretation of the data with respect to the death causes can be given based on the two tables. For all events in table 3 a major percentage of the deaths is due to persons swept into the water, eventually drowning. The fraction of car related deaths varies. A majority of the fatalities during the Hurricane Floyd were car related, similar high percentages of car related deaths for US states flash floods are reported by French et al. (1983). The fatalities occurring amongst rescuers are limited (varying from 0 – 8% of total known flood fatalities), but the hazards of rescue can not be completely neglected. Additionally, Duclos et al. (1991) indicate that 2 of the 9 deaths during the flash-floods in Nimes in 1988 were rescuers.

The amount of indirect fatalities due to traumas, heart attacks and electrocution, varies for the different events. Especially, during the Elbe 2002 floods in Germany the indirect deaths (4 heart attacks and 1 trauma) formed a substantial part (20%) of total flood fatalities. For other river flood events, no indirect fatalities were reported. This can be also due to the reporting, because in some cases the indirect fatalities might not be recorded as being flood victims.

The higher number of fatalities for the two coastal events can be attributed to the fact that these events occurred unexpectedly (see above). The rapidly rising water, leading to people trapped in buildings caused many fatalities. Both events can be considered as a kind of flash floods. It is striking that the distribution over the categories is similar for the two events, given the classification is based on qualitative reports and descriptions.

Overall conclusions for the relevance of and the distribution of fatalities over the different death causes for the different flood types cannot yet be drawn. Data for more events are required, and a standardized categorization and reporting is recommended.

Gender

Also an analysis of the gender of the known victims is given in table 5.

Table 5: distribution of (known) fatalities over the genders (data on gender were not available for the UK 1953 flood)

	Germany 2002		Poland 1997		Poland Wisla 2001		US 1999		Netherlands 1953	
flood type	river		river		river		hurricane		coastal	
male	15	60%	12	86%	12	86%	38	68%	906	49%
female	6	24%	2	14%	3	21%	18	32%	844	46%
unknown	4	16%							85	5%

This shows that for the river floods men are much more vulnerable than women. This may be related to the risk taking behaviour during these events: such as the entering of floodwaters and / or attempts to rescue people. The equal distribution of the fatalities over the genders for the Netherlands 1953 coastal flood may imply that in this unexpected coastal event both genders are equally affected, and the increased hazard associated with male risk taking behaviour is less relevant for these cases.

Age

In the appendix C data on the age distribution of the known fatalities is given. Although no final conclusions can be drawn with respect to the vulnerability of certain age groups, the data give a first indication that the elderly may be more vulnerable in floods, especially when related to certain death causes. For example all the 5 indirect deaths in the Elbe 2002 floods (4 heart attacks, 1 trauma) were persons aged over 65. Also elderly seem to be more vulnerable for other death causes: For example, the 14 deaths at Kings Lynn during the UK 1953 floods were all elderly, most of them trapped in buildings. An overall comparison of the age distribution of the flood deaths for the NL 1953 flood and the population age distribution for 1953 (www.cbs.nl) also suggests that elderly, in the age groups over 60, will be more vulnerable in floods. A reason might be the decreased possibilities of self rescue of elderly.

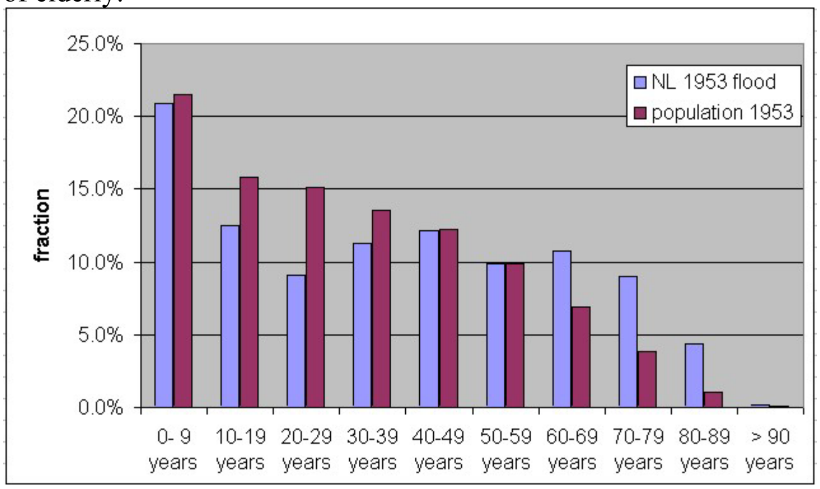


Figure 4: Comparison of distribution over the age categories for NL 1953 flood deaths and NL 1953 population

Australian flood fatalities
A study on 2213 flood fatalities in Australia, which occurred between 1788 and 1996 (Coates, 1999) discusses the death causes, and the distribution of the fatalities over age groups and gender. The Australian statistics indicate the hazards associated with the rescue process: of the total deaths 6,1% occurred while being rescued, 1,4% of deaths were rescue personnel and 3.4% of the fatalities were voluntary rescuers. The disparity between the numbers of professional vs volunteer rescuers killed is related to a lack of training. The figures also show that 8,3% of the fatalities occurred when victims attempted to retrieve stock or property and that 5,7% of the fatalities were persons undertaking recreational activities in the flooded area, stressing the importance of risk taking behaviour as a major source of death. With respect to the distribution of flood deaths over the genders, the Australian statistics show an over-representation of male flood deaths. This is related to the types of work carried out by males and risk taking behaviour. Finally, the article shows "a noticeable increase in fatalities amongst those aged over 59 and under 25, reflecting the inability of the elderly and the very young to flee, and the greater propensity for risk-taking amongst the youthful".

United States flash flood fatalities
Multiple sources are available on flash flood related fatalities in the United States. French et al. (1983) analysed information on 1185 fatalities for the period 1969 - 1981, Mooney studied (1983) 582 fatalities which occurred from 1977 through 1981. Although not discussed in detail here, these sources show similar findings with respect to death causes, and distribution over age and gender. On a yearly basis almost half of the (flash) flood fatalities are car related (43%: French, 1983, 49% Mooney, 1983) . Another major fraction of the people killed is due to persons which are swept into the water (French: 43%, Mooney 23%). The percentage of fatalities due to rescue efforts is reported to be a small amount of the total (French: 3%, Mooney: 2%). More recent the US National Weather Service data sheets on 571 flash flood fatalities for the period 1995 – 2000 show similar patterns with respect to death causes. The NWS data for the period 1995-2000 also show an over representation of male deaths (63% male vs 37% female). The NWS data and Mooney also indicate the vulnerability of children and elderly in floods.

As a conclusion of this section it can be stated that some first patterns emerge from these data with respect to death cause, and vulnerability of certain age groups and the distribution of victims over the genders However, as the amount of data analysed is still limited, no final conclusions can be drawn yet. Further structurized collection and interpretation of data is necessary for a better understanding of the problem.

Long-term mortality
A study on the health effects of the Bristol (UK) floods in 1968 showed an increase of mortality rates of 50%, while no appreciable change occurred in the non-flooded part of Bristol (Bennet, 1970). The number of malignant diseases (e.g. cancer) in the flooded area rose from 9 the year before the flood to 21 the year after. The other part of the increase of mortality is provisionally related to the psychological effects. Similar patterns in post-flood mortality were observed after the UK 1953 floods at Canvey Island (Baxter, 2001) and Canary Islands (French, 1989). However, another observation with respect to post flood mortality is given by (Duclos, 1991): no increased in mortality was after the floods in Nimes in 1988.

6 Concluding remarks

This annex describes the health effects of floods in general and compares attempts these descriptions with the effects observed for several flood cases. A study by Hajat et al. (2003) has a similar aim. Further integration with this study might be considered in order to strengthen the evidence on the potential occurrence and the magnitude of certain health effects.

There is some literature available which describes the health effects that could occur after a flood in general, such as (Ohl, 2000) (WHO, 2002). However, specific descriptions of health effects occurring after specific flood cases are seldom found in literature.

Health effects

The findings with respect to the different types of health effects can be summarized as follows:

- The number of reported injuries after a flood are relatively limited. and include sprains and fractures. During the clean up phase electrocution and carbon monoxide seem the most common hazards.
- Floods can potentially lead to outbreaks of illnesses and diseases, as is shown in some cases for mainly developing countries. However, the outbreak of diseases after floods in the US and Europe is rare. A significant hazard is the disruption of water supply.
- A potential danger induced by inundations is the release of hazardous, toxic materials. Although there potentially large consequences associated with these chain reactions, "information on adverse health effects associated with such exposures is limited" (French, 1989).
- Floods will impose a serious burden on public health facilities, before, during and after the flood. The demand on public health facilities will be equivalent with the magnitude of health effects of the floods. No serious disruption of public health services after floods have been reported for industrialized countries.
- The psychological stress experienced by flood victims will strongly influence mental and physical well-being. Psychological effects can continue to last for months and even years after the flood and are therefore an important consequence .
- Increased levels of malignant diseases and rises in mortality have been reported after floods, probably related to increased psychological stress.

Loss of life

Information on flood fatalities for several case studies covering different types of floods (river, coastal, hurricane) has been studied. Although no final conclusions can be yet drawn based on the limited amount of available data, some first patterns emerge from the various sources. The young and elderly are more vulnerable in floods. Males are over-represented in the flood death statistics. This could probably related to male risk-taking behaviour. A major percentage of deaths in European floods is believed to be connected to risk-taking behaviour. Several sources indicate the hazards associated with the rescue process, especially for voluntary rescuers. For the studied river flood cases main death causes were persons drowning after being swept in the water and the car related accidents. Also indirect causes, such as shock and heart attack, will contribute to death total.

Essential elements in the (prevention) of loss of life caused by a flood are the flooding conditions and the possibility of pre warning and evacuation. A study on worldwide flood statistics shows differences in mortality between the various flood types. Flash floods affect relatively little people but cause relatively high numbers of fatalities and result in high mortality. River floods result in higher numbers of affected, but relatively low mortality. Furthermore the way people respond to the exposures is a critical factor in the morbidity and mortality associated with such events (French, 1989)

Most of the observed effects are reported for relatively small scale floods. It is expected that a large scale floods affecting up to millions of people, as can potentially occur in the Netherlands, will have equivalently larger negative health effects.

Overall, the empirical evidence for the occurrence and magnitude of the different types of health effects is rather weak. Therefore there is a need for more and better quantitative data on health impacts associated with all categories of flooding. This includes centralized and systematic national reporting of deaths and injuries from floods using a standardized methodology (WHO, 2002). However, making a distinction between direct and indirect effects may be difficult: The public health impact of floods and other disasters may reflect secondary effects of the disaster, such as population displacement and disruption of existing health services (MMWR, 1993)

Insight in health effects basis for reduction of these impacts by taking precautionary measures, such as the preservation of safe water and food supply, inspection and monitoring of chemical sites and (toxic) waste sites. A more complete overview of actions to be taken is for example given in (CDC, 1993)

References

Baxter PJ, Moller I. Spencer T, Spence RJ, Tapsell S., Flooding in climate change, in: Health effects of climate change in the UK, Department of health, 2001

Bennet, G.,, Bristol floods 1968 – Controlled survey of effects on health of local community disaster, *British Medical Journal*, 3, 454-458, 1970.

Bierens J.J.L.M.,Drowning in the Netherlands – pathophysiology, epidemiology and clinical studies, isbn 90-393-1294-X, 1996

CDC. Beyond the flood: a prevention guide for personal health and safety. Atlanta: US Department of Health and Human Services, Public Health Service, 1993.

Climent J., Flooding in Somalia takes heavy toll, British Medical Journal Vol. 316, 1998

Coates L., Flood fatalities in Australia, 1788 – 1996, Australian Geographer, Vol. 30, No. 3, p. 391 – 408, 1999

Daley WR, Shireley L and Gilmore R, 2001, A flood-related outbreak of carbon monoxide poisoning – Grand Forks, North Dakota, Science Direct, journal of Emergency medicine vol 21, Issue 3 Oct 2001 pp 249-253

Duclos P., Vidonne O., Beuf P., Perray P., Stoebner A., Flash flood disaster Nimes, France, 1988, European Journal of Epidemiology, Vol. 7, No. 4 p.365 – 381, 1991

Easton Adam, Leptospirosis in Philippine floods, British Medical Journal Vol .319, p. 212, 1999

Flood Hazard Research Centre, The health effects of floods – the Easter 1998 floods in England, FHRC article series No. 3/99, 1999

French J., Ing. R. , von Allmen S., Wood R., Mortality from flash floods: a review of the national weather service reports, 1969 – 1981, Public Health Rep. 98 (6): 584 – 588, 1983

French JG, Holt KW. Floods. In: Gregg MB, ed. The public health consequences of disas-ters. Atlanta, Georgia: US Department of Health and Human Services, Public Health Ser-vice, CDC, 1989:69–78.

Hajat S, Ebi KL, Kovats S, Menne B., Edwards S, Haines A., The human health consequences of flooding in Europe and the implications for public health, to be published in: Journal of Applied Environmental Science and Public Health, 2003.

Jonkman, S.N., An analysis of mortality for worldwide floods, draft document, 2002a

Jonkman S.N., P.H.A.J.M. van Gelder and J.K. Vrijling, An overview of loss of life models for sea and river floods, in: *Proc. Flood Defence '2002*, Wu et al. (eds). Science Press, New York Ltd., ISBN 7-03-008310-5, 2002b

Kelman I, Physical Flood Vulnerability of Residential Properties in Coastal, Eastern England, University of Cambridge, U.K., 2002

McCarthy, et. al., Climate change 2001: impacts, adaptation and vulnerability, IPCC, 2001 (http://www.grida.no/climate/ipcc_tar/wg2/index.htm)

MMWR 1993 a, Morbidity and Mortality Weekly Report, Morbidity Surveillance Following the Midwest Flood — Missouri, Vol. 42 No. 41, 1993

MMWR – Public health consequences of a flood disaster – Iowa, 1993, MMWR Vol. 42 No. 34, 1993

MMWR –Morbidity and mortality associated with hurricane Floyd – North Carolina, September – October 1999, MMWR Vol. 49 / No. 17 p.369 – 372, 2000

Mooney L.E., Applications and implications of fatality statistics to the flash flood problems in: *Proceedings of the 5th conference on hydrometeorology*, Tulsa USA, 1983

Roos, W., P. Waarts and A. Vrouwenvelder, Damage to buildings, Delft Cluster paper, 2003.

Tapsell SM. *Follow-up study of the health effects of the Easter 1998 flooding in Banbury and Kadlington. Report to the Environment Agency.* Enfield: Flood Hazard Research Centre, 2000

Tuffs A., Bosch X., Health authorities on alert after extensive flooding, British Medical Journal, Vol. 325, p. 405, 2002

Waarts, 1992

World Health Organization – regional office for Europe, Floods: climate change and adaptation strategies for human health, 2002

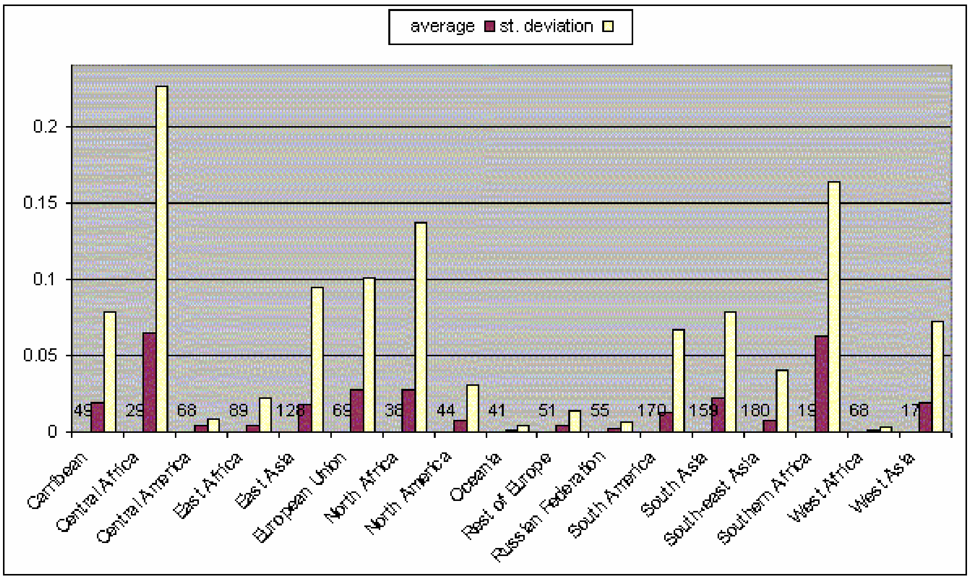
Sources from which data on flood fatalities for cases in table 3 was abstracted

Elbe 2002: http://www.sachsen.de/de/bf/hochwasser/katastrophe/tote_verletzte/index.htm
Poland 1997 & Poland 2001: Personal communication with Malgorzata Mierkiewicz (Imgw)
Hurricane Floyd 1999: Hurricane Floyd floods of september 1999, US Department of commerce, June 2000, www.***
Netherlands 1953 Waarts, P.H.; Methode voor de bepaling van het aantal doden als gevolg van inundatie (Method for determining loss of life caused by inundation, in Dutch), TNO, september 1992

Zeeuws archief, ***********
UK 1953:
Summers, D., The east coast floods, 1978
Grieve, H., The great tide, Waterlow & sons limited, 1959
CURBE factsheet 3: UK Deaths from the 1953 Storm Surge disaster, http://www.arct.cam.ac.uk/curbe/infosheets.html#factsheet3

Appendix A: Flood mortality by region

17 regions are defined in the OFDA / CRED disaster database. Figure … shows the average mortality by flood event for the 17 regions.



Appendix B: Mortality statistics by flood type

Table ** shows the average number of killed people, affected persons for the four flood types.

	killed			Tot Aff		
Type	number	average	st. deviation	number	average	st. deviation
Coastal	18	36	59	17	77820	122701
Drainage problems	68	12	37	68	156873	770639
Flash	225	187	1996	195	55537	242907
River	383	121	359	367	3373529	18913976

Appendix C: Age distribution of flood deaths for some cases

Table presents …..

Flood	Germany Elbe 2002		Poland 1997		Poland Visla 2001		Hurricane Floyd, 1		Netherlands 1953		UK 1953	
type	river		river		river		hurricane Floyd		coastal		coastal	
Year / period	aug-02		July 1997		July 2001		sep-99		febr 1 1953		febr 1 1953	
Affected area	Elbe / Dresden		Odra, Wisla		Wisla		East Coast		Southwest NL (Zeeland)		East Coast	
Total affected	330000		62000		15000		264000				32000	
Total killed	27		55		27		77		1835		313	
Age												
0- 9 years	0	0%		0%	2	13%	6	12%	375	20%	20	
10-19 years	0	0%		0%	1	7%	3	6%	224	12%	1	
20-29 years	0	0%	1	3%		0%	5	10%	164	9%	2	
30-39 years	4	16%	2	7%	3	20%	3	6%	203	11%	20	
40-49 years	1	4%	1	3%	3	20%	13	26%	218	12%	4	
50-59 years	6	24%	2	7%	2	13%	10	20%	177	10%	2	
60-69 years	2	8%	2	7%	3	20%	6	12%	193	11%	43	
70-79 years	5	20%	1	3%	1	7%	7	14%	161	9%	36	
80-89 years	1	4%	1	3%		0%	3	6%	78	4%	21	
> 90 years	0	0%		0%		0%	0	0%	3	0%	0	
unknown	6	24%	4	14%		0%	0	0%	39	2%	rest	
Total known	25		14		15		56		1835		149	