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The health and health care system impacts of earthquakes, windstorms and floods- *A Systematic Review*

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List of abbreviations

ARI	Acute Respiratory Infection
CI	Crush Injury
COPD	Chronic Obstructive Pulmonary Disease
CRED	Centre for Research on the Epidemiology of Disasters
CS	Crush Syndrome
DF/DHF	Dengue Fever/Dengue Hemorrhagic Fever
FFH	Foreign Field Hospital
HIV/AIDS	Human Immunodeficiency Virus/ human Acquired ImmunoDeficiency Syndrome
JE	Japanese Encephalitis
PAHs	Polyaromatic Hydrocarbons
PCBs	Polychlorinated Biphenyls
SMEs	Small and Medium Enterprises
SPM	Suspended particle matter
SVOCs	Semi Volatile Organic Compounds
VOCs	Volatile Organic Compounds
TB	Tuberculosis
WHO	World Health Organization

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1 Introduction

Disasters result from the impact of extreme events (intense physical phenomena) on human life and environment. A disaster is described as “serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources”(UN-ISDR 2004). The Center for Research on the Epidemiology of Disasters (CRED) defines a disaster as a situation or event, which overwhelms local capacity, necessitating a request for national or international external assistance (CRED 2007).

1.1 Aims and objectives

The current document focuses on the health and health systems impacts of natural disasters specifically earthquakes, windstorms and floods. The purpose is to review the existing body of evidence based knowledge and identify gaps by performing a review of scientific publications and grey literature. Physical and mental health impacts at individual and population levels are considered along side the impacts at the health care system level.

1.2 Disaster classification

Disasters are classified on the basis of the causative agents into natural and man-made disasters (Guha-Sapir 2001). Natural hazards are further classified into hydro-meteorological and geophysical events become “natural disasters” when impacting human lives and livelihood although human activity itself, such as land use change, often strongly influence the outcome of a disaster. Man-made disasters, also called technological disasters, include those resulting from human actions (Table 1).

Table 1: Classification of disasters (CRED 2008a)

Natural Disasters	Technological Disasters
Hydro-Meteorological Avalanches/ landslides, droughts, extreme temperatures, floods, forest/scrub fires, windstorms and other disasters such as insect infestations and wave surges	*Industrial Accidents* Chemical spills, collapses of industrial infrastructure, explosions, fires, gas leaks, poisoning and radiation
Geophysical Earthquakes, tsunamis and volcanic eruptions	*Transport Accidents* By air, rail, road or water means of transport
	Miscellaneous Accidents Collapses of domestic/non-industrial structures, explosions and fires

<u>Definition and classification of earthquakes</u>

According to (USGS 2007) “a sudden movement of the earth, caused by the abrupt release of long accumulated strain from within the Earths crust”, earthquakes are classified based on the intensity and magnitude.

<u>Definition and classification of windstorms</u>

Windstorms are classified according to their intensity measured according to the top sustained wind speed and are referred to as cyclones, typhoons, hurricanes, tropical storms or depressions, depending of their strength and geographical location (see glossary and Table

A1). Windstorms are often accompanied with heavy rains leading to flooding and increased risk of land- and mudslides. During windstorms the damaging factors are linked to high wind-speed, storm surge, and heavy rainfalls and flooding. This leads to damages to buildings, infrastructure vegetation, and coastal features. In coastal areas strong winds cause storm surge, i.e. displacement of sea water unto land, leading to coastal flooding.

Definition and classification of Floods

The causes and impact of flooding vary depending on circumstances and geographical settings and speed of the event and distinguish into slow-onset, rapid-onset and flash-floods. River floods are caused by overflowing banks unto plain areas. The speed of the onset distinguishes floods into slow-onset flooding occurring over days or weeks is typical of large rivers and affects large areas. Rapid-onset flooding occurs over hours or days typically from rivers that received heavy rainfall and have localized impacts affecting smaller geographical areas (Hajat et al. 2005). Heavy rainfall can lead to floods when drainage is insufficient; urban areas that are characterized by impervious surfaces (i.e. surfaces where water cannot infiltrate, such as road and paved parking lots) are prone to this type of floods. Flash-floods occur within minutes or hours following heavy rainfall or structure collapse. However, not all floods are disasters. In many places floods are events of annual occurrence. They may bring positive aspects such as fertilization of the fields and are seen as beneficial events. Floods become disasters when they are of unusual proportion, occur in unusual places, or occur unexpectedly. In coastal areas flooding is often caused by tidal surge following a windstorm bringing sea water unto land.

Disasters also differ according to their predictability, initial lethality, scope of geographical impact, and onset delay time. Fig. 1 ranks common disasters along this multidimensional scale. Earthquakes are characterized by short onset delay, high lethality, low predictability, and localized impacts. Earthquakes remain highly unpredictable since although the theory of plate tectonics is very useful in explaining earthquake occurrence, the short-term triggers still remain unclear. “The lack of adequate warning contributes significantly to the maintained vulnerability of people to disasters” (Blaikie et al. 1994). Floods in contrast have a slower onset, are more predictable and less lethal but can affect larger areas. Cyclones and windstorms rank between earthquake and floods on this scale.

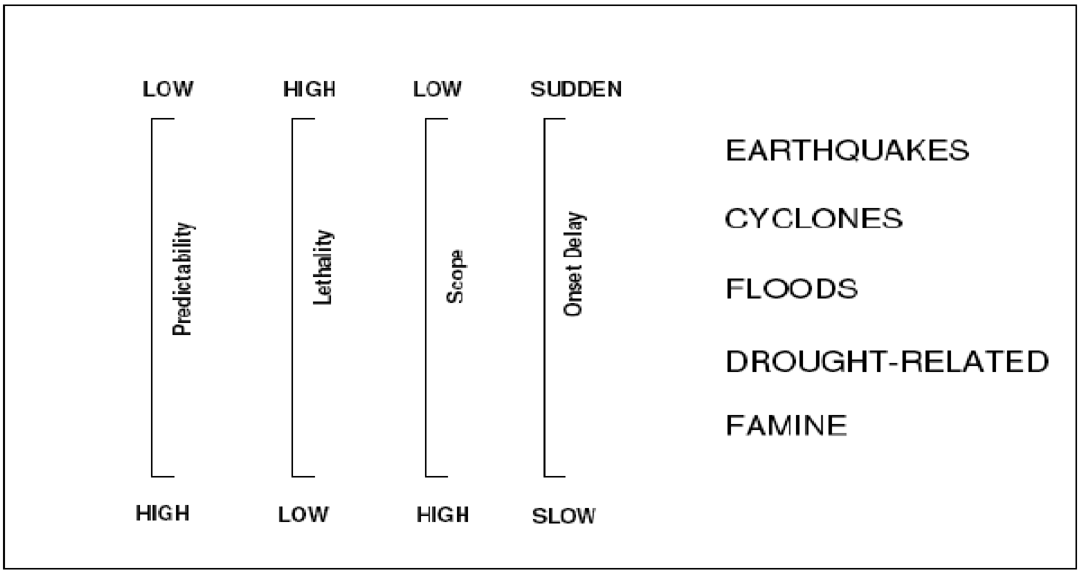

Figure 1: Disaster characteristics assessment scale (Guha-Sapir 1986; Guha-Sapir and Lechat 1986b)

1.3 Geographical distribution and frequency of disasters

Higher frequencies of natural disasters occur in developing countries (Guha-Sapir 1986; Guha-Sapir and Lechat 1986a). Amongst other factors, poorly controlled urban development, rapid population growth in disaster prone areas and lack of appropriate preparedness explain the increase in the overall impact of disasters. According to the United Nations, "one of every two large cities in the developing world is vulnerable to natural disasters" (Noji 2005). Asia, being the largest and the most populous continent, has been worst hit by natural disasters. The World Disasters Report, 2006 states that between 1996 and 2005, Asia as a continent reported the highest number (2,660 of total 6,417) of disasters in the world. Over 250 million people were affected annually during this period and almost 90% of them were in Asia (IFRC 2006).

Floods are the most common natural disaster. Of the 235 natural disasters reported in 2006 more than half were floods. Between 1990 and 2007, 2274 flood events were reported, 896 floods in Asia and 331 in Europe (EM-DAT 2008). An estimated 281 earthquakes occurred in 58 countries from 1996-2005 causing death of more than 162,986 people, affecting 39 million with economic damages of US$ 94 billion (CRED 2006). Between 1990 and 2007, 498 earthquakes were recorded as disasters and 21 events were estimated killing at least one thousand people with all but two occurred in Asia (Table 5). Those two earthquakes were estimated to have killed over 224,000 and affected over 21 million persons. The most severe event occurred in October 2005 in Kashmir; a region divided between Pakistan and India, and claimed the life of nearly 74,000 people. Asian countries are more prone to earthquakes as it is a seismically active region. Indonesia ranked 1st amongst the most affected countries in 2006 (CRED 2007).

Among the 1771 windstorms reported during the same period, five countries in Asia and five in the Americas experienced the 15 deadliest events with nine events (60%) occurring in Asian countries. Table 2 summarizes the frequency and the number of deaths and affected in specific country of interest to MICRODIS related to earthquakes, windstorms and floods (2000-2007).

Table 2: Frequency of earthquake, windstorm, and floods and number of deaths and injured in specific country of interest to MICRODIS between 2000 and 2007 (Source: "EM-DAT: The OFDA/CRED International Disaster Database Created on: Sep-15-2008.)

		Earthquake (including Tsunami)			Flood			Storm		
Continent	Country	N	Total affected	Sum of killed	N	Total affected	Sum of Killed	N	Total affected	Sum of killed
Asia	India	4	7133146	37705	83	227433643	10576	23	822454	679
	Indonesia	31	4912920	173580	45	2907310	2576	2	3715	4
	Philippines	1	73451	15	27	1450006	318	56	26370115	5170
	Viet Nam	0	0	0	30	9623800	1806	25	5073276	761
Europe	Belgium	0	0	0	6	2610	2	2	2	7
	France	0	0	0	18	53674	44	13	2452	52
	Germany	1	150	0	5	331558	29	13	451	76
	Italy	4	9774	30	12	57592	55	2	0	1
	United Kingdom	0	0	0	12	373638	15	7	23104	53
Total Affected: Sum of injured, affected and homeless, N= Total episodes of natural disaster										

1.4 Disaster myths and realities

Disasters generate unusual traumatic situations and their aftermaths are likely to trigger panic reactions, irrational behavior, and misconceptions. A number of disaster myths are vividly observed and the most relevant are reviewed below.

Corpse and corpse disposal

The presence of dead bodies does not trigger epidemics, as is often reported. Though dead bodies are psychologically disturbing and unpleasant to handle, they do not represent a direct health threat (Eberwine 2005; Gottlieb 2004; World Health Organization). One reason is that the proportion of corpses infected with epidemic disease organisms mirrors that of the living population and is usually low; another reason is that most pathogens do not survive for more than a few hours after the host dies (Morgan 2004). However, leaching of intestinal pathogens from cadavers can lead to contamination surrounding water supplies but the effect is usually spatially limited (Morgan 2004). Providing safe water to survivors in post-disaster situation should be a high priority, given that water supplies are even more likely to be contaminated by the living than by the dead.

People directly handling dead bodies should take adequate hygienic precautions to reduce the risk of infectious hazard associated with occupational handling of the dead (Morgan 2004; PAHO 2006). In particular, precaution should be taken to avoid exposure to blood-borne viruses such as Hepatitis B/C and HIV shown to survive in the body for up to 16 days after death; gastrointestinal pathogens (such as rotavirus, salmonellosis, typhoid, paratyphoid, shigellosis, cholera) that can be transmitted though feaces; and tuberculosis, as *Mycobacterium tuberculosis* can be aerosolized and survive for an extended time (Morgan 2004).

Hasty burial in mass graves for fear of contamination is unnecessary and counterproductive; leading to great psychological distress when survivors look for their loved ones, do not know if they have died, cannot recover the bodies for proper mourning ceremonies, and find themselves in indefinite legal status (Eberwine 2005). Cremation without adequate identification should be avoided. Burial in swallow graves is preferred while taking necessary steps to allow for later exhumation and identification of the deceased is essential for legal, social, and psychological reasons (Eberwine 2005).

Survivor behavior and needs

It is often assumed that affected populations are helpless when to the contrary survivors are often ready to help and organize themselves to help those affected. First aid is often provided by people present at the site and by the affected themselves as even in the best case scenario, outside and international aid does not arrive before hours or days after the disaster strikes. Indiscriminate aid and a flow of ill-suited supplies, even if well-intentioned, are not helpful but often contribute to existing chaos. Rather, responding to local demand and providing expertise where it is needed is a more pragmatic approach. Although the emergency phase of the disaster phases out after a few weeks, survivor needs continue long time after the acute phase is over and after most of the emergency teams and NGOs have left. Recovery is a long term process that can take months or even years (PAHO 2006).

1.6 Impact of disasters on health and health care systems

One important commonality that disasters share is the health impact pathways. Although their intensities and nature may differ, the outcome to a large extent could be similar.

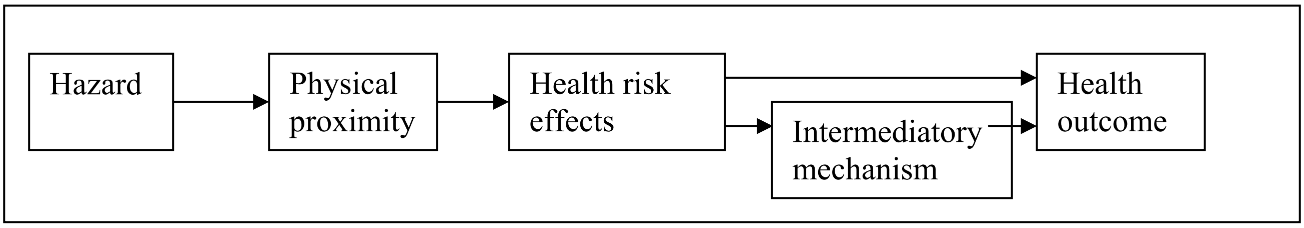

Figure 2: Generalized health impact pathway for climatic hazards (Few 2007)

Figure 2 shows the simplified pathway for health impacts applicable to natural disasters such as floods or earthquakes. It is useful to understand the scope and complexity of proximal and distal factors affecting these causal pathways. It also identifies the potential entry points for effective interventions. Health impacts include mortality and morbidity in term of injuries, increased transmission of infectious diseases, inadequate treatment of non-communicable and chronic diseases (e.g. problem with drug procurement), disability, and psychological effects. Health systems impacts include the failure of the system as a whole to cope with the disaster. It may be a direct result of physical damage due to the disaster or an indirect result due to systemic failure through supplies exhaustion for example. Systemic failures of parallel infrastructure such as the water and sanitation system or emergency housing system as well as transport and communication system could lead to secondary impacts on the overall health care delivery to the affected population. Often the exaggeration of baseline diseases and increased transmission of communicable infectious diseases result from systemic failures. Access to food could also influence the general condition of the population including malnutrition status and the lack of adequate immunity thereof. Figure 3 summarizes in general the health and health systems impacts of natural disasters

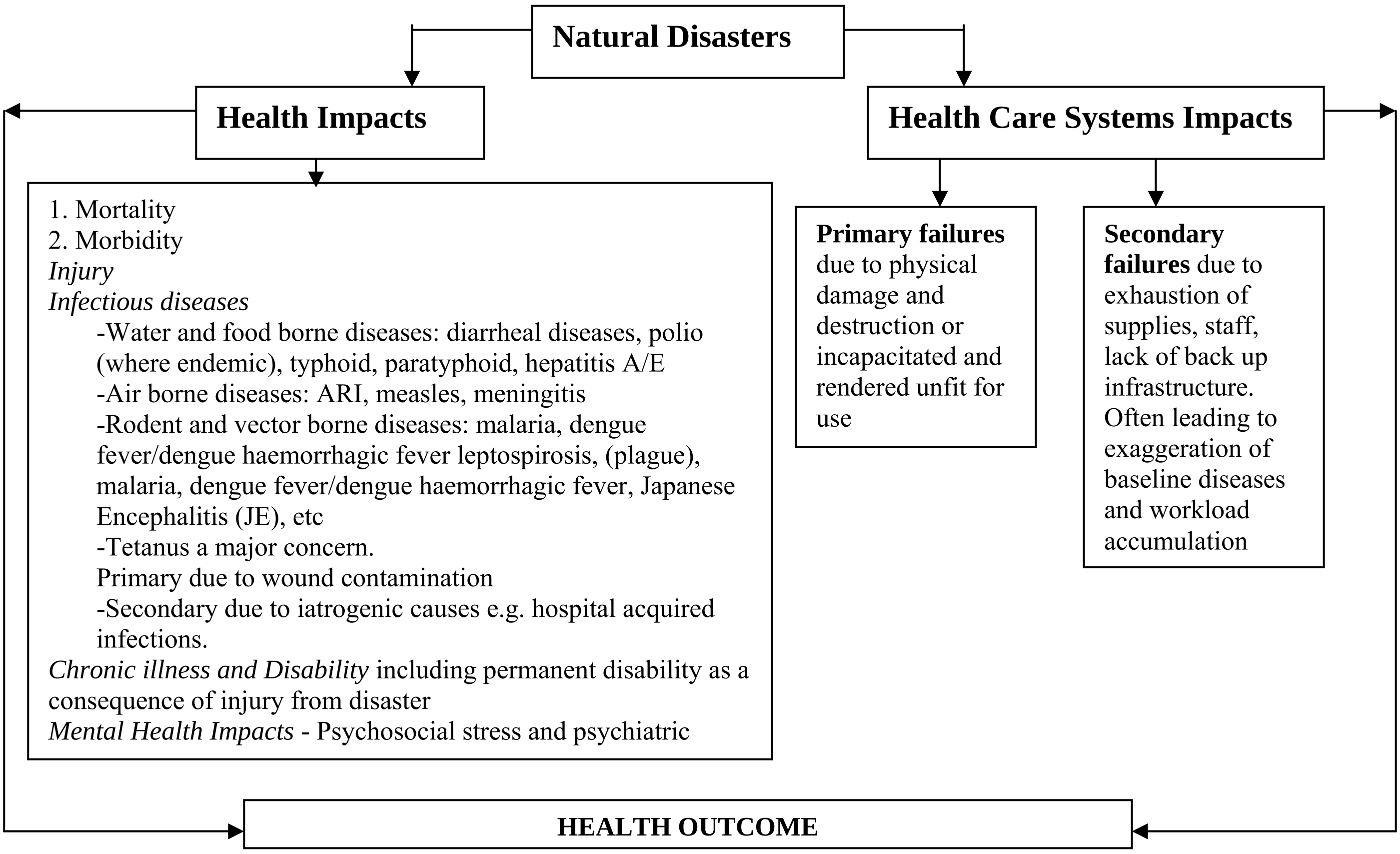

Figure 3: General health and health systems impacts of natural disasters

2. Methods

The systematic literature followed broadly the AMSTAR recommendations for methodological quality (Shea 2007). It was performed both electronically and manually. For the electronic search the following online databases were accessed: PubMed, Lexis Nexis, Medline, Blackwell Synergy, and Science Direct,Web of Science, Google Scholar, NLM Gateway, Cochrane Library, OFDA/EM-DAT database. Extensive systematic article search was carried out for floods in the library of the Institute of Tropical Medicine (Antwerp) and library of the Centre for Research on the Epidemiology of Disasters (CRED) (Brussels).

First a high sensitive search was performed applying the exclusion criteria in order to identify relevant articles, followed by the inclusion criteria. Key words, MeSH terms inclusion and exclusion criteria are described in Table 3. The references from full text papers were manually viewed for further articles. Articles were screened on the basis of titles and abstracts when available. The following search strategies were applied and the studies systematically reviewed have been enlisted for earthquakes and windstorm in the Tables 4 and 5 below. The 124 studies reviewed for floods have not yet been enlisted here.

Table 3: Adopted search strategies for literature

Search Criteria	Earthquakes	Windstorms	Floods
Key terms and MeSH terms	earthquake, health impact, trauma, injury, epidemiology, seismology, field hospital, musculoskeletal, disasters response and natural disasters.	storm*, windstorm*, cyclone, hurricane, typhoon, health disease*, disaster, mortality, morbidity, infectious, mosquito*, vector*, water-born*, rodent-borne, diarrhea*, diarrhoea*, respiratory*, chronic, health system, health care system, and specific storm names such as Katrina, Mitch, Gorky, Sird	"climate" or "climate change" or "disaster" or "flash floods" or "floods" or "flooding" or "hurricane" or "natural disaster" or "precipitation" or "rainfall" or "storm" or "tsunami" AND "adapt" or "adaptation" or "anxiety" or "cholera" or "chronic diseases" or "chronic" or "death" or "dengue" or "depression" or "diarrhea" or "diseases" or "displacement" or "fever" or "gastrointestinal" or "health" or "health status" or "HIV" or "HIV/AIDS" or "hypertension" or "infection" or "infectious" or "infectious diseases" or "illness" or "injury" or "leptospirosis" or "malaria" or mental health" or "mitigation" or "mortality" or "mosquito" or "prevention" or "poisoning" or "PTSD" or "public health" or "rodent" or "skin" or "strategy" or "surgery" or "trauma" or "vector" or "west nile" or "wound
Inclusion criteria	Published studies reporting individual patient clinical data for morbidity (injuries and illness) after earthquakes	Review studies and studies reporting clinical data	Review studies and studies reporting clinical data
Exclusion criteria	Articles dealing exclusively with mental health. Preference given to the most recent papers and to original research (instead of review papers). When similar	Articles dealing exclusively with mental health. Preference given to the most recent papers and to original research (instead of review papers). When similar information was given by different	Articles dealing exclusively with mental health. Preference given to the most recent papers and to original research (instead of review papers). When similar information was given by different sources, preference was given to the most recent one.

Search Criteria	Earthquakes	Windstorms	Floods
	information was given by different sources, preference was given to the most recent one.	sources, preference was given to the most recent one.	
Languages included	English	English, French, German and Spanish	English, French and Spanish
Timeperiod of search	Open ended Search ended on November, 30 2007	Open ended. Search ended on May 16, 2008	Open ended. Search ended on the 1st of April 2008
Total numbers of hits assessed by title and/or abstract			
Articles assessed full text	136	150	268
Articles included in result section	29 The Kashmir earthquake study by Dhar et al., 2007 (Dhar et al. 2007) the author was contacted for raw data. The study by Shoaf et al., 1998 (Shoaf et al. 1998) reported data on three different locations as hence these were treated as separate studies in the analysis.	16	124

Studies reviewed on earthquakes

Table 4: Overview of the published earthquake literature studies analyzed

Location and Date	Time Intensity	References	Study design Target pop.	Sample size
Guatemala February 4, 1976	03:02 7.2	(de Ville de Goyet et al. 1976;de Ville de Goyet 1976)	Patient in Hospital in city of Jalapa in Guatemala at day 1 after earthquake	157 patients
Southern Italy November 23, 1980	19:34 NA	(De Bruycker et al. 1983) (De Bruycker et al. 1985)	House-to-house retrospective survey, random sampling from population registers; standard questionnaire	3619 people in 7 villages
Mexico City, September 19, 1985	NA 8.1	(Sanchez-Carriallo 1989)	Medical records from hospital and emergency units	822 inpatients
Yunnan Province, China November 6, 1988	21:03, 21:06 7.6, 7.2	(Guha-Sapir and Panaccione 1992)	Data from local hospital (Kunning preventive hospital)	128 patients
Southern Hyogo, Japan, January 17, 1995	05:46 7.2	(Yoshimura et al. 1996)	Medical records of patient in local hospital	487 patients
Hanshin Awaji, Japan January 17, 1995	05:46 7.2	(Tanaka et al. 1999)	Retrospective study of medical records in 95 hospital in disaster and surrounding area	6107 patients in 95 hospitals

Location and Date	Time Intensity	References	Study design Target pop.	Sample size
Armenia December 7, 1998	11:41 6.9	(Armenian et al. 1997)	Population-based cohort study for long term surveillance and monitoring; interview of employee of the ministry of health and their family	7016 interviews
Whittier Narrow, USA October 1987	NA 5.9	(Shoaf et al. 1998)	Random-digital-dial (rdd) telephone survey	690 residents
Loma Preita, USA October 1989	NA 7.1	(Shoaf et al. 1998)	Random-digital-dial (rdd) telephone survey	656 residents in 5 counties
Northridge, USA January 17, 1994	04:31 6.7	(Shoaf et al. 1998)	Computer assisted telephone interviews (CATI)	1830 residents
Northridge, USA January 17, 1994	04:31 6.7	(Peek-Asa et al. 1998)	Coroner's and medical records from Los Angeles county hospitals	171 patients
Northridge, USA January 17, 1994	04:31 6.7	(Mahue-Giangreco et al. 2001)	Medical records at four hospitals	4190 patients, 418 earthquake-related
Chi Chi Taiwan September 21, 1999	01:47 7.3	(Yi-Szu et al. 2000)	Medical records of trauma patients transferred to Taichung Veteran General Hospital	164 patients
Marmara, Turkey August 17, 1999	03:04 7.4	(Bar-Dayan et al. 2000)	Patients from the Israeli Defense Forces field hospital	1205 patients
Marmara, Turkey November 12, 1999	22:00 7.2	(Bar-Dayan et al. 2005)	Patients from the Israeli Defense Forces multidisciplinary field hospital	2230 patients
Marmara, Turkey August 17, 1999	01:37 7.4	(Dönmez et al. 2001)	Children with crush syndrome transferred to one health center	20 children with crush syndrome
Marmara, Turkey August 17, 1999	03:02 7.4	(Iskit et al. 2001)	Medical records of children aged 14 days-16 years in one hospital reviewed retrospectively	33 pediatric trauma victims
Marmara, Turkey August 17, 1999	03:02 7.4	(Öncul et al. 2002)	Medical records in one hospital reviewed retrospectively	630 patients
Marmara, Turkey August 17, 1999	03:01 7.4	(Sarisözen and Durak 2003)	Medical records in one hospital reviewed retrospectively	659 patients
Kutch, Gujarat, India January 26, 2001	08:46 6.9	(Roshchin and Mazurenko 2002)	Field observations from a disaster medicine camp	5558 patients
Kutch, Gujarat, India January 26, 2001	08:46 6.9	(Jain et al. 2003)	Patients from Mobile field hospital	1142 inpatients, 62 pediatric surgeries
Kutch, Gujarat, India January 26, 2001	08:53 6.9	(Roy et al. 2002)	Interview of patients in Gandhi-Lincoln hospital with "Victim Specific Questionnaire"	643 patients (not clearly stated)
Kutch, Gujarat, India January 26, 2001	08:46 6.9	(Roy et al. 2005)	Follow up on non-urban victims having been treated at the Gandhi-Lincoln hospital	133 patients from 11 villages
El Salvador January -February 2001	NA NA	(Woersching and Snyder 2003)	Convenience sample survey; 32-question survey	594 persons within 100 households
Bam, Iran December 26, 2003	05:26 6.5	(Emami et al. 2005)	Retrospective survey based on medical records of patients evacuated to Chamran hospital specialized in orthopedic and neurosurgery	708 patients
Bam, Iran December 26, 2003	05:30 6.8	(Tahmasebi et al. 2005)	Descriptive analysis of patient admitted to a tertiary referral trauma management center in Tehran.	210 patients
Kashmir, Pakistan October 8, 2005	09:20* 7.6	(Dhar et al. 2007)	Medial records from one hospital	568 patients in 10 days
Kashmir, Pakistan	08:50**	(Vanholder et al. 2007)	Renal Disaster Relief Task Force	88 victims with

Location and Date	Time Intensity	References	Study design Target pop.	Sample size
October 8, 2005	7.6		(RDRTF), 22 days in Islamabad area	broadacute kidney injury
Kashmir, Pakistan October 8, 2005	NA 7.6	(Bozkurt et al. 2007)	Patients from Turkish Red Crescent Field hospital prospectively evaluated	2892 patients

*Indian standard time; **Pakistan standard time; NA: not available

Studies reviewed on windstorms

Table 5: Selection of the windstorm literature reporting clinical data

Event, location and date	References	Study design Target pop.	Sample size
Hurricane Andrew, Florida and Louisana, Aug. 1992	(Combs et al. 1993)	Death attributed by medical examiners to Hurricane Andrew in Florida and Louisiana	55 deaths
Cyclone Gorky, Bangladesh, April 1991	(Bern et al. 1993).	Rapid epidemiological assessment; Nonrandom survey of 45 housing clusters in disaster zone	1123 individuals in 135 households
Cyclone Gorky, Bangladesh, April 1991	(Barrios et al. 2000)	Anthropogenic measurements of children under five in 3 region in Honduras	295 children under five
Hurricane Mitch, Gulf of Mexico, Oct 1998	(Guill and Shandera 2001)	San Pueblo Community in Northern Honduras (5000 persons); survey of randomly chosen adults in an ambulatory relief clinic	110 respondents
Hurricane Mitch, Gulf of Mexico, Oct 1998	(PAHO 1998)	Epidemiological surveillance from ministries	
Super-cyclone in Orissa, October 1999	(WHO 2000) (Sehgal et al. 2002)	Population of four villages (approx. 12500 people) near River Baitarani. Sample persons interviewed and blood was collected for laboratory test.	142 persons
Super-cyclone in Orissa, October 1999	(Chhotray et al. 2002)	Diarrhea patients from hospitals and primary health centers; rectal swabs tested for *V. cholerae*	107 hospitalized diarrhea patients
Series of 3 hurricanes 2004, Florida	(Platz et al. 2007)	Retrospective analysis of 3 cohorts in two emergency department in central Florida	5145 patients
Hurricane Katrina, Louisiana and US Gulf coast, Aug 2005	(Greenough et al. 2008)	Population-based cluster sample: 2-stage, clusters in American Red Cross shelters	18499 evacuees
Hurricane Katrina and Rita, Louisiana and US Gulf coast, Aug 2005	(Tak et al. 2007)	Survey on floodwater exposure among firefighters	525 survey respondents
Hurricane Rita, Texas, Sept 2005	(Cukor and Restuccia 2007)	CO poisoning in Texas	21
Hurricane Katrina and Rita, Louisiana and US Gulf coast, Aug 2005	(CDC 2006b)	Hospital and acute-care facilities in the greater New-Orleans area; active surveillance for injuries and illnesses	17446 visits
Hurricane Rita, New Orleans, Sept 2005	(Chen et al. 2007)	Mixed-methods, survey and focus group among Vietnamese-American survivors	113 Vietnamese Katrina survivors
Hurricane Katrina, New Orleans and Mississippi, Aug 2005	(Messias and Lacy 2007)	Face to face interviews with Latino survivors and evacuees	93 Latino survivors and evacuees
Hurricane Katrina, Louisiana and US Gulf Coast, Aug 2005	(Callaghan et al. 2007)	Data from National vital statistic systems, screening for preterm and low birth weight in areas affected by Hurricane Katrina	74859 births
Hurricane Katrina, Louisiana and US Gulf Coast, Aug 2005	(Messias and Lacy 2007)	Semi-structured interview ; convenience sample among Latinos survivors and evacuees in Atlanta, New Orleans, Biloxi and Gulfport	93 Latinos survivors and evacuees

3. Health Impacts

3.1 Vulnerability and population at risk

Vulnerability as defined by the WHO is "The degree to which a socio-economic system is either susceptible or resilient to the impact of natural hazards and related technological and environmental disasters. The degree of vulnerability is determined by a combination of several factors including hazard awareness, the condition of human settlements and infrastructure, public policy and administration, and organized abilities in the various fields of disaster management. Poverty is identified as one of the main causes of vulnerability in most parts of the world (WHO 2008). Vulnerability can be individual or as per a group (population/community vulnerability). Individual vulnerabilities for health impact result from pre-morbid conditions and illnesses, or by demographics such as gender and age. Population vulnerability could also be a function of the physical location like for example population settlements on encroached river banks that are prone to frequent flooding or earthquake fault lines which are zones of maximal seismic activity. This leads to heightened risk from the hazard. In general the vulnerable population poses risks due to prevailing social and economic conditions that shape the distal crucial parameters. For example, family income, illiteracy rate, level of schooling, and location of work are some additional factors contributing to the vulnerability of a population to earthquake impacts (Blaikie et al. 1994). Since all these factors are mutually influential, an integrated overview is necessary to understand the close interactions to accelerate efforts directed towards community preparedness and mitigation planning.

Penning-Rowsell et al. have identified four groups that need to be located and targeted for assistance for effective public health management: the elderly, those with prior-event health problem, the poor, and those with dependents, especially children (Penning-Rowsell et al. 2005). In the following section we will list the main groups identified as vulnerable in the reviewed literature.

Infants and pregnant women, children, the elderly

People with special need such as the elderly, pregnant women and infants can be exposed to potentially damaging conditions for example pregnant women and infants are more sensitive to exposure to contaminants and such occurrence may have more serious consequences than for the rest of the population (Callaghan et al. 2007). After Hurricane Katrina, many residents were left without food in the days following the impact and this was particularly difficult for pregnant women and small children (Messias and Lacy 2007). In Bangladesh 1991 Gorky cyclone excess mortality was recorded in children under 10 and in females, especially those over 40 years of age and many fatalities were linked to people not reaching safe shelters or attempting to do so too late, factors such as physical size, strength and endurance were assumed to have played a role in survival (Bern et al. 1993). In the sample considered all persons who were able to reach a hard-construction shelter survived. Children and the elderly, who may have difficulties reaching shelters by themselves, should be encouraged to do so early.

Premorbidity

Persons with chronic health conditions and the disabled suffer a greater burden during and after the disaster. Chronic disease exacerbations are frequent and account for the largest patient populations during and after disaster in some areas (Miller et al 2008). Miller states that 25-40% of those living in the regions affected by hurricanes Katrina and Rita lived with at least one chronic disease. Chronic illness accounted for 33% of patient visits in the aftermath of the disasters. Inadequate or interrupted treatment often leads to adverse health condition during and after the disaster. Disaster preparedness needs to address chronic diseases in order to ensure timely treatment for those affected and prevent additional mortality.

Minorities and migrants

Minorities and migrants may face a higher burden compared to general population, as they may not receive clear information due to language barrier, may not have the necessary resources to evacuate, may have limited access to health care systems, or may fear to seek help because of their immigration status. Messias and Lacy depict the experiences of the Latino community (i.e. residents originating from Central and South America and predominantly Spanish-speaking) after Hurricane Katrina. Several were ill-prepared as they did not grasp the danger posed by the up-coming storm and underestimated the severity of the situation. The message from the main-stream media did not reach them in a way that would prompt them to react appropriately to the imminent threat. Given the circumstances and the of lack preparedness several went hungry in the days following the disaster (Messias and Lacy 2007). Access to health care remained a problem and people who were not in the country legally avoided shelters provided by the government for the fear of being expelled from the country. A study among Vietnamese-American survivors showed that legal and language barrier accentuated strain after the disaster and that those who were less integrated suffered more physical and mental health problems (Chen et al. 2007). Financial issues were a major source of worry. Though within migrant communities the support of family and friends plays a crucial role, it is important to reach out to them.

Displaced populations

Evacuation and sojourn away from home create stress. As mentioned above, individuals with special needs, whose pre-morbid condition may deteriorate during that time and who may not receive adequate care for some time afterward, are especially at risk of adverse health impact during evacuation process and residence in shelters. The conditions characterizing the displacement such as overcrowding, impoverishment, poor health care access, decreased access to safe water and sanitation and the disruption in public health programs such as vector control programs, immunization and disease surveillance make displaced populations more vulnerable (Connolly et al. 2004). The movement of people from areas of low endemicity to hyperendemic areas puts them at a higher risk of infectious diseases, such as malaria for example (Wilder-Smith et al 2005). In the aftermath of the Indian Ocean Tsunami, some health conditions such as upper tract respiratory infections were reported in high proportions among displaced populations (Watanabe 2007). Overall, the main health threats in displaced populations in low-income countries are communicable diseases, mainly diarrheal diseases, acute respiratory infections, measles and malaria in endemic areas (Spiegel 2007).

Low social-economic status

Higher mortality rate in natural disasters has clearly been associated with lower socio-economic conditions (GUHA-SAPIR D. et al. 2006). For instance, poor housing plays a major role in natural disasters such as earthquakes, storms and floods. Construction type, age of the building, height of the dwelling, material used, occupancy rate, type of use (commercial, residential, public use) and structural pattern greatly influence the number of casualties. It has also been noted that structures of brick or local materials collapse into rubble with little or no room for survivors making building material an important concern (Jones 2006).

Special Exposure to Chemical contamination (The full text of chemical contamination and Floods by Marita Luotamo and Kai Savolainen is included in *Appendix 2*)

Chemical contamination can pose immediate or long-term health problem particularly after floods. Although often neglected, especially in less developed countries, it is a serious problem from both a human health and an environmental point of view and adds to the vulnerability of a population to additional health impacts. Globally there are over 100 000 chemicals in different uses in different industrial sectors including large scale industries and small and medium size enterprises, agriculture including professional and home scale activities, and gardening. The uses of chemicals also include cleaning and disinfection at public institutions and homes, and other uses such as the production and distribution of pharmaceutical and cosmetic products. Thus, chemicals are present everywhere in societies and communities although volumes used and toxicities vary greatly. The methods used in producing, storing, using, transporting and discharging of chemical and chemical-containing products play a critical role in managing the risk of contamination in case of floods. Chemicals may be released into the floodwater from industrial, agricultural and domestic storage (e.g. underground fuel tanks), or by remobilization of chemicals already present in the environment such as metals and pesticides. Flooding potentially increases the amount of chemicals that run off from farms, lawns, and streets into rivers, lakes and coastal waters (Euripidou and Murray 2004). Table 11 illustrates these processes through an overview of major flooding events in Europe and the Americas.

Table 11: Summary of past experiences of floods and chemical contamination

Event, location , date	Description	Hazard and Chemicals	References
Inundations after Hurricane Katrina New Orleans, USA Aug. 2005	-Possible contamination of the soil and sediments due to release from: chemical plants, manufacturing facilities, refineries, homes and other buildings, and crude-oil tank failure but effect limited spatially and most likely transient. -Absence of major toxic contamination due to: -dilution factor -alkaline pH of water -High concentrations of molds, bacteria, and airborne mold spores in moisture-damaged structures causing allergies and asthma among many of the exposed	-elevated concentrations of Pb, As and C, VOC, lead (mainly in location with historically high concentration) -floating debris	(Pardue et al. 2005) (Roper et al. 2006) (EPA and CDC 2008) (Van Metre et al. 2006)
Minnesota River flood, Minnesota USA, Summer 2002	-Intense precipitation events resulting in extraordinarily wet conditions in East-Central and North-Western Minnesota	-Elevated methyl mercury concentrations due to leaching from terrestrial areas to surface waters	(Balogh et al. 2006)(Balogh, Swain et al. 2006)
Flood after Hurricane Mitch, Honduras October 1998	-Flood and mud slides -Elevated concentrations of chlorinated and organophosphate pesticides showed that substances banned for 15 years were still in use. -Most common self-reported symptoms were headache (44.4%), tiredness and weakness (42.2%), skin rash (40%), abdominal pain (33.3%), fever (27.7%), decreased appetite (24.4%), chills (22.2%) and nausea (22.2%)	-Elevated levels of pesticides (DDT and organophosphate metabolites) in soil but not water -Soil levels of chlopyrifos and parathion 30- and 1000-times higher than authorized, respectively -Elevated levels of chlorinated and organophosphate pesticides in serum (more in adolescents than in adults)	(Balluz et al. 2001).
Mackenzie Delta Canada	-Canada's longest river and largest delta covering Delta covers an area of 13,500 km^2 and contains approximately 25,000 lakes	-Concentration of PAHs decreased with decreasing flooding frequency and decreasing sedimentation rates.	(Headley et al. 2002)
Flooding in the UK, Yorkshire and Humber, East Midlands, West Midlands, South West, South East Central and London Summer 2007	-Risks low to the general public due to dilution by floodwaters -Reduce risk by avoiding contact with floodwaters	-Chemical -Pathogens from sewage in floodwater	(HPA 2007).

Event, location , date	Description	Hazard and Chemicals	References
Flooding in central Europe Elbe river Germany, Poland and Czech Republic Aug 2002	-Flooded chemical factories (e.g. Spolana chemicals factory in Czech Republic, producing basic chemicals, pharmaceuticals and plastics) -Flooded chlorine tanks releasing 80 tons of chlorine and diluted in the flood waters; small amounts released in the air -Soil and sediment contaminated by dioxin and related compounds -flooded sewage treatment works	- dioxins (PCDD/F) -xenoestrogen-like branched nonylphenols (NP), likely the discharge of treated waste water from the sewage plant - elevated concentration of Monobutyltin (MBT), dibutyltin (DBT), and tetrabutyltin (TeBT) in several areas, traced to discharges from a manufacturer of antifouling agents and the local shipyards. - phosphates and nitrates, silicates and most heavy metals were within normal range -Mercury concentrations in sediments elevated at some sites, but still below mid-1990s values. -For alpha-HCH and beta-HCH up to 10-fold elevated concentrations were observed. Some herbicides like atrazin showed about 5-fold elevated concentrations - Some herbicides like atrazin showed about 5-fold elevated concentrations - As and Hg were occasionally present in higher concentrations. Cd, Pb and Ni concentrations were not elevated -Increased sediment concentration of some organic compounds (BaP, β-HCH, PCB, DDT, HCB, Dioxin and MKW), often at sites were PCB and DDT were elevated - elevated concentrations of insecticide metabolites detected in flounder livers and digestive glands of blue mussels in the Elbe estuary and the Wadden Sea. -In Czech Republic at the River Malše: flooding caused leaching of heavy metals present from bottom sediments into the environment	(Stachel et al. 2003;Stachel et al. 2005) (Danihelka 2008) (Anacker et al. 2003) (Einsporn et al. 2005) (Chrastny et al. 2006)
Flood, Dese River, Venice Lagoon, Italy Summer 2002		-increased levels of Fe, Cu, Pb, Cr, Ni and particularly Zn in water samples highly correlated to suspended particle matter (SPM)	(Zonta et al. 2005)
Flood, Guadiamar River, Spain, 1998	-herbicides mobilized into the aquatic environments when prairie agricultural landscapes subjected to torrential storms and flooded	-high concentration of pesticide in wells and small municipal reservoirs - heavy metal concentrations in soils with deposited sludge (As, Au, Pb, Sb, Tl and Zn) higher than upper limits for normal soils	(Donald et al. 2005) (Cabrera et al. 1999)
Seine River and tributaries, France Fresh floodplain deposit 1994-2000		- metal concentrations (Cd, Cu, Hg, Pb and Zn) elevated by a factor of two or more after flooding	(Grosbois et al. 2006)

Public health impacts of chemicals in floods in UK, an example

Euripidou and Murray (Euripidou and Murray 2004) reviewed three floods related to chemical incidents in England i.e. the Yorkshire flood (2000), the Gloucestershire fire and floods (2000) and the Kent floods (October 2001). These floods were chosen, because the chemical contamination had the potential to affect public health either primary from soil or water and secondary from homes or via other contamination. This was verified by demonstrating that one or more chemicals were found in land, homes, flooding sediment or water in concentrations above or soil guideline levels with a potential to cause both acute and chronic adverse health effects.

- In Yorkshire, from October 28 through November 8, 2000, severe flooding due to high rainfall caused the risk to clean-up workers to be exposed to dioxins (2,3,7,8-TCDD), because this area was earlier heavily contaminated with elevated levels of dioxins by heavy industry. There was evidence that dioxin residues became mobilized from rivers, canals, storm water and sewage drains.
- In Gloucestershire, a fire destroyed approximately 160 tons of hazardous waste containing drums including a wide range of chemicals such as cyanide, resins and adhesives, pesticides, solvents, asbestos and low level radiation waste.
- In Kent, during floods in October 2001 vast amounts of oil waste was mobilized by the flood waters and 140 people were evacuated to rest centers while over thousand were displaced (Euripidou and Murray 2004). Euripidou and Murray (Euripidou and Murray 2004) Table 12 summarizes the chemicals that caused possible contamination and their sources.

Table 12: List of chemical contaminants reported after the 2001 flood in Kent, UK (Euripidou and Murray 2004)

Flooding	Source	Chemical contaminants
Storm water floods	run-off from roads, motorways and bridges	- heavy metals - pesticides, fertilizers and herbicides - hydrocarbons - oils and grease - petrol and fuel depots - spilled petroleum products - paint and rust - sodium and chlorine
Overloaded sewers	sewer pipes - residential, industrial or storm water - run off – remobilization	- variety of residential, industrial and storm waste water - domestic and industrial sources
Hazardous landfill sites	physical contamination	- hydrogen sulphide and mercaptan - persistent chemicals - asbestos - mercury
Wastewater lagoon	contamination of soil, sediment or groundwater	- VOCs - PAHs - dioxins - persistent chemicals, e.g. wood preservatives
Acid mine drainage	coal mines	- sulphides - oxidation to sulphuric acid - aluminum, arsenic, cadmium, cobalt, copper, iron, lead, manganese, nickel, silver and zinc

3.2 Mortality

The number of deaths is a reliable indicator of human loss in a disaster but represent only a small part of the impact. It was estimated that for each person killed in a disaster 3000 people are exposed (UNDP 2004). Preparedness, improved disaster forecasting, early warning systems, emergency planning and shelter availability play a key role in reducing the number of casualties due to direct the impact of a disaster (CDC 2006d). Developed countries have seen the number of casualties reduced with the majority of deaths now occurring in the post-disaster phase (Bourque et al. 2006). However, developed countries still suffer heavily and disproportionately from storm mortality (Table 8).

Primary Mortality- Directly related mortality

Mortality related to a disaster occurs both through its direct impact such as structural collapse, flying debris, wind, storm surge, as well as indirectly through the circumstances associated with a disaster (Combs et al. 1999) distinguish between directly-related deaths and indirectly-related deaths linked to loss or disruption or services on one hand and personal loss or lifestyle disruption on the other hand (Table 6). They propose to record casualties into a two-dimensional matrix classifying death through direct and indirect circumstances (rows) versus manner of death (columns). This approach gives an overview of the causes of death in relation to risk factors.

Secondary Mortality- Indirectly related Mortality

Indirectly related death results from unusual circumstances or disruptions created by the disaster (Table 6) leading to situations that contribute to increase the mortality (Combs et al. 1999). In the post-disaster phase, sources of hazard arise from loss or disruption of services such as transportation, public utilities and health care. Disruptions of public utilities such as electricity, gas, running water, functional sewage and solid waste system, may lead to unsanitary conditions or push people to engage in dangerous and potentially fatal behavior. For example, use of candle as source of light can turn fires (CDC 1998). Deaths due to carbon monoxide poisoning are a common feature when power supply is disrupted and residents use electricity generators without ensuring proper ventilation of the device (Cukor and Restuccia 2007). Even when used outdoors generators may cause poisoning when CO seeps into rooms through air-conditioning units.

In disaster-struck areas, damaged roads impede rescue and relief effort through reduced accessibility or delayed access to health care facilities. Disruption services in health care facilities due to actual physical damage or lack of medical personnel leads to delayed medical care and increase the risk of fatal outcomes (Combs et al. 1993). Furthermore lack of telephone service may prevent a timely transport to a health facility for treatment and result into a fatal outcome of an otherwise treatable condition.

Returning to weakened and unsafe buildings and engaging in clean-up and reconstruction operations can present life-threatening situations, especially if safety precautions are disregarded. Examples of fatalities in such instances include electrocution after contact with damaged electrical wires and deaths caused by falling trees (CDC 1998),.

Table 6: Classification and coding matrix to assess mortality attributed to natural disaster (adapted from (Combs et al. 1999))

Cause, manner of death / **Circumstances**	Accidental (A), Homicide (H), Suicide (S), Fetal (F), Undertermined (U)							Other	Cause, manner of death: natural (N)		
	Asphyxia drowning	Blunt, penetrating Trauma		Other trauma		Poisoning		Specify cause, manner	Allergies, adverse effects	Medical conditions	Infectious diseases
		Acute	Late effect*	Electro cution	burns	Exposure to element	Carbon monoxide				
1. direct effects: environmental forces											
Wind and storm surge Structural collapse, flying debris											
Geophysical event: (e.g. mud slide)											
2. Indirect effect: loss or disruption of services											
Loss or disruption of transportation-related services											
Loss, disruption of public utilities											
Exposure to industrial hazard											
Loss, disruption of usual access to medical, mental health care											
Social disruption, anarchy											
3. Indirect effects: personal loss, lifestyle disruption											
Evacuation											
Use of temporary sheltering, provision; displacement											
Preparation for disaster, clean up after disaster											
Return to unsafe, unhealthy structures or environment											
Psychosocial stress, anxiety											

* e.g. wound infection

Mortality related to earthquakes

Earthquakes are high lethality disasters and were responsible for almost 27% of all deaths from natural disasters over the last 30 years (CRED 2007). Table 7 summarizes the earthquakes between 1990 and 2007 recording more than 1000 deaths. These are primarily attributed to the serious injuries sustained and difficulties of rescue or immediate relief (Guha-Sapir 1993). This is also the reason why mortality once rescued is low. However, if the serious injured are rescued immediately the primary mortality may decrease but secondary mortality due to delayed deaths may increase. Thus this has to be interpreted in view of effectiveness of the rescue and immediate relief. All in all most report that secondary deaths were far lower in frequency (De Bruycker et al. 1983).

Table 7: Earthquakes 1990-2007 recording 1000 or more deaths (source: EM-DAT, 2008)

	Date	Continent	Country	Location	Killed	Affected
1	Oct 2005	Asia	Pakistan	Bagh, Muzzafarabad, Kashmir	73338	5128000
2	June 1990	Asia	Iran	Rasht, Astara, Zanjan	40000	710000
3	Dec 2003	Asia	Iran	Bam (Kerran province)	26796	267628
4	Jan 2001	Asia	India	Kutch-Bhuj, Ahmedabad	20005	6321812
5	Aug 1999	Asia	Turkey	Izmit, Kocaeli, Yalova	17127	1358953
6	Sept 1993	Asia	India	Killari, Haegoan	9748	30000
7	May 2006	Asia	Indonesia	Yogyakarta, Central Java	5778	3177923
8	Jan 1995	Asia	Japan	Kobe, Osaka and Kyoto region	5297	541636
9	May 1998	Asia	Afghanistan	Shari-I-Buzurg (Faizabad)	4700	116935
10	Dec 1992	Asia	Indonesia	Sikka, East Flores, Ende	2500	92103
11	July 1990	Asia	Philippines	Cabanatuan, Baguio, Dagup	2412	1597553
12	Feb 1998	Asia	Afghanistan	Rustaq (Takhar province)	2323	32818
13	May 2003	Africa	Algeria	Thenia, Boumerdes,	2266	210261
14	Sept 1999	Asia	Taiwan	Nantou, Taichung County	2264	108664
15	May 1995	Eurasia	Russia	Neftegorsk	1989	750
16	May 1997	Asia	Iran	Birjand, Qayer (Khorasan)	1568	74600
17	Oct 1991	Asia	India	Harsil (near Gangotri	1500	54383
18	Oct 2005	Asia	India	Jammu and Kashmir	1309	156622
19	Jan 1999	Americas	Colombia	Armenia (Quindio)	1186	1205933
20	Feb 1997	Asia	Iran	Ardabil region	1100	38600
21	Mar 2002	Asia	Afghanistan	Nahrin (Baghlan province)	1000	91228

Mortality related to Windstorms

Table 8 presents the windstorms occurring worldwide between 1990 and 2007 that recorded 1000 or more deaths (EM-DAT 2008). It is estimated that nearly 195,000 deaths occurred and that over 63 million people were affected by these storms. The deadliest tropical cyclone in this period was cyclone "Gorky" that hit Bangladesh in April 1991 and claimed nearly 140,000 lives, or over 70% of fatalities reported here. The second deadliest storm was Hurricane Mitch that hit central America in October-November 1998, claimed approximately 19,000 lives and affected over 3 million people (data source: (EM-DAT 2008)).

In Asia, Bangladesh, the Philippines suffered a five-fold increased in the number of storms with over 1000 deaths between the first and the second reported period (Shultz et al. 2005). In contrast to this trend however, Hurricane Katrina making landfall near the city on New Orleans in August 2005 made nearly 1500 victims in Louisiana only (Louisiana Department of Health and Hospitals 2006) and with over 1800 fatalities countrywide was the deadliest since 1928 (CDC 2006e). The part of the population that was unable or unwilling to evacuate, mostly the poor, suffered most from the impact. This event showed that even in developed country the poor and vulnerable groups bear disproportionally the burden of disaster in terms of mortality and morbidity (Greenough et al. 2008).

Table 8: Windstorms 1990-2007 recording 1000 or more deaths (source EM-DAT, 2008)

	Date	Continent	Country	Location	Type	Name	Killed	Affected
1	Apr 1991	Asia	Bangladesh	Chittagong to Cox's Bazar, offshore islands	Cyclone	Gorky	138866	15438849
2	Nov 1998	Americas	Honduras	Coastal Area	Hurricane	Mitch	14600	2112000
3	Oct 1999	Asia	India	Kendrapara, Jagatsinghpur	Cyclone	05B	9843	12628312
4	Nov 1991	Asia	Philippines	Bago, La Cariota,	Typhoon	Thelma (Uring)	5956	647254
5	Nov 2007	Asia	Bangladesh	Khulna-Barisal Coast	Cyclone	Sidr	4234	8978541
6	Nov 1997	Asia	Viet Nam	Ca Mau, Soc Trang	Typhoon	Linda	3682	1081127
7	Nov 1998	Americas	Nicaragua	Chinandega and Esteli	Hurricane	Mitch	3332	868228
8	June 1998	Asia	India	Kutch, Porbandar, Jamnaga...	Cyclone	03A	2871	4600893
9	Sept 2004	Americas	Haiti	Artibonite, Plateau Central...	Hurricane	Jeanne	2754	315594
10	Sept 2005	Americas	United States	Louisiana, Florida, Mississippi, Texas Alabama	Hurricane	Katrina	1833	500000
11	Nov 2004	Asia	Philippines	Isabela (Region II), Bula...	Tropical storm	Winnie	1619	881023
12	Oct 2005	Asia	Guatemala	Escuintla, Jutiapa,	Hurricane	Stan	1513	475314
13	Dec 2006	Asia	Philippines	Daraga town, Bicol Region	Typhoon	Durian (Reming)	1399	2562517
14	Aug 1994	Asia	China	Fujian, Zhejiang, Jiangsu...	Typhoon	Fred (9416)	1174	11001800
15	Nov 1994	Americas	Haiti	Jacmel, Port au Prince	Storm	Gordon	1122	1587000

Between 1980 and 2000 the Philippines experienced the highest frequencies of tropical cyclones with reported deaths (UNDP 2004) but Bangladesh registered more than 60% of all windstorm-associated deaths, a figure still holding true in recent years (Table 8).

Deaths caused directly by windstorm results mainly from collapsing structures, flying debris and falling objects (Shultz et al. 2005). Trees and tree branches falling on train tracks and roads are a source of train and traffic accidents. Storm surges may lead to drowning: in the 1991 Bangladesh cyclone, 22% of people who could not reach a safe place (i.e. a hard-construction building) drowned in flood waters (Bern et al. 1993). Flash floods that often accompany windstorms can also cause drowning, with persons caught in vehicle being at a significant risk, especially in the United States where 42% of drowning were shown to be car-related (French et al. 1983). Heavy rains may trigger landslides and mudslides leading to further casualties (PAHO 1998;Sidle and Ochiai 2008;Zubair 2004).

Another important aspect leading to increased mortality arises from physical stress related to the occurrence of the storm and/or evacuation that may precipitate the fatal outcome of a pre-existing medical condition. The elderly and patients in intensive care are especially sensitive to this. A study after hurricane Andrew (Combs et al. 1993) showed that nearly 40% of indirect deaths were caused by stressed-induced cardiovascular events leading to natural deaths occurring prematurely up to 2 weeks after the disaster. Distress due to loss or mental stress may also lead to suicidal tendencies.

Mortality related to Floods

Table 9 shows the floods that occurred worldwide between 1990 and 2007 and recorded 1000 or more deaths (EM-DAT 2008). All but three of this 22 deadliest flood event occurred in Asia where most affected people are located in the highly populated countries of China, India, Bangladesh and Pakistan. China with nearly 800 millions people affected accounts for over 80% of the total over this period. The deadliest event reported, however, took place in Venezuela in December 1999 where in this case most victims died because of land slides. The exact number of deaths is unknown but estimated at 30,000. Among the floods reported in Europe between 1990 and 2007, three accounted for more than 100 deaths (maximum 168 in Novorossiisk, Russia, 2002), eight for more than 40 deaths and 18 for more than 20 deaths.

The majority of death related to flood occur by drowning or trauma as people are hit by floating objects (Ahern et al. 2005). As was shown in Poland during a summer flood of the great amplitude in 1997, underestimating the risk posed by fast moving waters caused additional deaths, especially in males. Death caused by motor vehicles being washed away in flashed flood is common, especially in the USA (Kundzewicz and Kundzewicz 2005).
The death toll following floods is particularly high in Asia, notably in Bangladesh, India, and China (see also Table 2). Population preparedness seems to help reduce flood fatality Appropriate maintenance of flood protections such as levees, dikes, and channels is essential because failure of these systems leads to devastating consequences and potentially high fatalities. This was illustrated in post-world war II Japan where poor maintenance lead to catastrophic failure of flood defenses in major cities and more recently in New Orleans after Hurricane Katrina (Kundzewicz and Kundzewicz 2005).

Table 9: Floods 1990-2007 recording 1000 or more deaths (source EM-DAT, 2008)

	Date	Continent	Country	Location	Type	Killed	Affected
1	Dec 1999	Americas	Venezuela	Federal district Caracas	Flood	30000	483635
2	Aug 1998	Asia	China	Hubei, Hunan, Sichuan	Flood	3656	238973000
3	July 1996	Asia	China	Anhui, Guizhou, Hebei	Flood	2775	154634000
4	June 2004	Americas	Haiti	Fonds Verrettes	Flood	2665	31283
5	Nov 1997	Africa	Somalia	Gedo, Middle, Lower Juba	Flood	2311	1230000
6	Oct 1994	Asia	India	Assam, Arunachal Pradesh	Flood	2001	12060050
7	Aug 1998	Asia	India	Assam, Arunachal, Bihar	Flood	1811	29227200
8	July 1991	Asia	China	Anhui, Jiangsu, Henan	Flood	1729	210232227
9	Sept 1995	Asia	India	Bihar, Haryana, Punjab	Flood	1479	32704000
10	Sept 1997	Asia	India	Andhra Pradesh, Arunachal ...	Flood	1442	29259000
11	Aug 1995	Asia	China	Hunan, Jiangxi, Guizhou	Flood	1437	114470249
12	May 1992	Asia	Tajikistan		Flood	1346	63500
13	Sept 1992	Asia	Pakistan	Azad Kashmir and Punjab	Flood	1334	6655450
14	Aug 2005	Asia	India	Gujarat, Madhya Pradesh	Flood	1200	20000055
15	Aug 1996	Asia	China	Yangtse, Haihe, Tianijn	Flood	1200	
16	Aug 2007	Asia	Bangladesh	Bandarban Hill, Feni	Flood	1110	13771380
17	Sept 2207	Asia	India	Bihar, Uttar Pradesh	Flood	1103	18700000
18	Sept 1998	Asia	Bangladesh	Mymensingh, Jamalpur	Flood	1050	15000050
19	Aug 1993	Asia	Nepal	Taplejung, Pantchthar	Flash flood	1048	553268
20	June 1994	Asia	China	Guangdong, Guangxi, Hunan	Flood	1001	78974400
21	Mars 1998	Asia	Pakistan	Kech Valley (Baluchistan)	Flood	1000	200000
22	June 1993	Asia	China	South	Flood	1000	

3.3 Morbidity

3.3.1 Injury

The frequency, mechanism and nature of injuries differ disproportionately after floods, windstorms and earthquakes. Dealing with injured patients is a major challenge after earthquake compared to windstorms or floods. Recording and reporting of disaster-related injuries is often inaccurate and incomplete and therefore often underestimated (Hajat et al. 2005).

Following windstorms, physical injuries are common from falling or flying objects, collapsing structures. Lacerations, blunt trauma and puncture wound are the most frequent with feet and lower extremities most often affected (Shultz et al. 2005). Other trauma such as abrasions, contusions, cuts, sprains and fractures are also common. Such injuries and strain can occur in the pre-disaster phase when people protect their home against the storm; furthermore an increased risk of traffic accident is observed during mass evacuation (Shultz et al. 2005). However, people unable to evacuate or weathering the storm in inadequate shelters are at particularly high risk of serious injury or death. Again, populations in developing countries are disproportionally affected. During Floods, injury and trauma are common when being hit by floating object or when people have to wade into flooding waters. Most commonly reported injuries include sprains, strain, lacerations, abrasion, and contusions.

The injury to mortality ratio of most earthquakes has been observed to be about 3:1 (Ramirez and Peek-Asa 2005). Thus, injury is a major health impact particularly after earthquakes and hence the following section focuses mainly on injury epidemiology after earthquakes. Falling debris and entrapment pose the greatest risks for injuries. A large number of injuries also occur due to being trapped in between objects or being hit by furniture (Peek-Asa et al. 1998). Entrapment after an earthquake poses serious risks including the lack of oxygen, asphyxia, body compression, hypothermia, smoke, and water penetration (Redmond 2005). A detail understanding of the mechanisms of injury and the building components causing injuries can help direct preventive efforts (Shoaf et al. 1998).

Injury severity

Most injuries sustained after the earthquakes were simple contusions, lacerations, cuts and minor soft tissue injuries. These are usually treated on an outpatient basis and seldom documented. Over 50% of the studies reporting injury morbidity reported data on single hospital in-patients. Majority of the 29 studies reviewed found in-patient data more complete than out patient data. Not all studies reviewed injury severity on a standardized scale. Often injury reporting was amongst the survivors and no concrete study reporting injuries post-mortem. Those sustaining severe injuries particularly serious injuries for chest, head, and abdomen die either due to delayed rescue or due to inadequate first aid and response(Tanaka et al. 1999). Second the injury distribution described in all studies was amongst the "survivors". The study by Peek-Asa et al., did not complete the autopsies on all deceased but observed that commonest injuries seen in those dead were head (48.5%), thoracic (42.4%) followed by abdominal and lower extremity injuries (Peek-Asa et al. 1998). Another study reported similar findings and stated that although the total percentage of head, abdominal and thoracic injuries constituted less than 7.5% of the total injured, the mortality in this group was the highest (Tanaka et al. 1999). Most of the chest injuries seen in the hospitals were of the minor type (Yi-Szu et al. 2000;Yoshimura et al. 1996). This was a similar finding in almost all studies as regard to head and abdominal injuries. Spinal cord injuries reported constituted mainly of burst vertebral type and often with associated spinal paraplegia. No detailed discussions of the outcomes have been sited.

Crush injury and crush syndrome

Most serious injuries from earthquakes come from being trapped under or between heavy objects. "Crush syndrome (CS) is the systemic manifestation of rhabdomyolysis caused by prolonged continuous pressure on muscle tissue. It is characterized by hypovolaemic shock, hyperkalemia, acute renal failure and muscle necrosis. The first cases of Crush Syndrome were reported during the Sicilian earthquake in Messina in 1909" (Dönmez et al. 2001). Crush syndrome is clearly related to the building design (Tanaka et al. 1999). It is more common in concrete multi-story building collapse. This was seen in the earthquakes in Japan and Armenia. In the study of morbidity after the Hanshin-Awaji Earthquake of 1995, and Armenian earthquake of 1988 reported higher number of Crush syndrome cases (Tanaka et al. 1999). Far lower numbers were reported in Nicaragua, Guatemala and Iran due to the mud and adobe construction or probably due to a poor rescue operation or both. Thus, the number of patients developing crush syndrome seems to also be related to the rescue time.

The early clinical signs of crush syndrome if recognized and treated urgently with appropriate medication, fluid resuscitation and dialysis can help prevent death. The incidence of acute renal failure is reduced mainly by administration of intravenous fluids at rescue (Dhar et al. 2007). Unfortunately first responders, rescue workers, paramedics and even untrained nephrologists are unfamiliar with recognizing early symptoms. This is further compounded by the lack of infrastructure for dialysis to cope with the mass casualties (Vanholder et al. 2007). This problem however arises only when the search and rescue level is effective enough to retrieve these patients alive in large numbers. This was demonstrated in the Gujarat earthquake where less than two percent cases of crush syndrome were reported a documented case of poor rescue performance (Cooper 2006).

Crush injury (CI) occurs when a body part is subjected to a high degree of force or pressure that leads to bleeding, bruising, increased pressure in the compartment, fracture and lacerations (Medical Encyclopedia 2007). Crush syndrome is common in children with crush injuries along with a higher risk to develop acute renal failure (Dönmez et al. 2001;Iskit et al. 2001). This is further compounded by the difficulty in diagnosis both clinically and diagnostically (Iskit et al. 2001). Close monitoring of children is therefore solicited to detect early signs. Another aspect with crush injuries is secondary complications due to heightened risk of secondary infections, gangrene and amputations of the affected limb(s) thereof (Personal observation during the work in Gujarat).

Table 10 summarizes the frequency of earthquake related injuries as reported in the literature. Fractures were the most common orthopedic injury. The most frequent amongst these apparently are extremity fractures, lower extremities more common than the Upper Extremities. Dislocations are far less and were rarely reported. Multiple fractures and compound fractures are common. Although one study attributed frequent extremity fractures and clavicle fractures to the day time earthquakes and axial or trunkal injuries to night time earthquake essentially due to the position, no such association was empirically evident in the studies reviewed.

Table 10: Data variables mentioned in the 29 studies reviewed (Phalkey 2007)

Variable	Number of 29 studies reporting variable	Number of studies reporting variable as most frequent health condition	Percentage of patients enrolled who were affected in the 29 studies. (% range in the studies)
Medical faculty			
Psychological Trauma	7		0-32%
Orthopedic	8	2	15-45%
General Surgery	2		6-13%
Internal Medicine	6	1	30-79%
Gynecology	5		5-22%
Pediatric	2	1	23-37%
Syndromes			
Cardiovascular Disease	3		3-16%
Fractures	5	1	20-55%
Crush Syndrome	6		1-26%
Crush Injury	5		5-46%
Acute Renal Failure	6		2-69%
Infections	6		5-47%
Upper Extremity	10	Humerus	10-30%
Physical injuries			
Extremity Injuries	9	6	19-55%
Lower Extremity Injuries	10	7, Femur	30-54%, 1 study 4%, 1 study 7%
Clavicle	7		0-1%, 1 study 11%
Spinal	11		4-16%
Pelvis	6		3-13%
Trunk	2	1	6-55%
Head	12		0-30%
Chest	7		3-19%
Abdominal	9		0-15%
Burns	5		2-16%
Compound Injuries	2		4-6%
Multiple Injuries	7		3-50%
Amputations	7		1-20%
Soft Tissue Injuries	16	6	10-83%
Peripheral Nerve Injuries	6		1-9%
Secondary Deaths	8		2-23%
Others	9		3-77%
Transfers	5		0-25%
Unknown	1		10%

3.3.2 Infectious diseases

The incidence of infectious diseases after disasters is largely due to disrupted systemic infrastructure. Earthquakes have minimal direct impact on the transmission of communicable diseases. Secondary failures of water and sanitary systems leading to poor hygiene as well as incapacitated health service systems per se cause a rise in infectious disease cases. However epidemics are rare and so are diseases of crowding (Waring and Brown 2005). Accumulated cases emerge at the end of the emergency phase. Secondary wound infections and tetanus are potential threats due to contamination in populations where immunization levels are low (Guha-Sapir et al. 2007). However, concern with tetanus particularly in developing countries has not been documented adequately to arrive at useful conclusions (Waring and Brown 2005). The falling debris and construction material also pose risks for wound contamination.

Post operative infection rates have not been sufficiently studied or documented. Given the overall hygienic condition and post disaster situation, the incidence is expected to be higher than in baseline hospital settings. However, just one study reported hospital acquired infections for etiology but not overall incidence (Öncul et al. 2002). Contact with contaminated environmental waters can cause wound infections, notably through *Vibrio vulnificus* and *V. parahaemolyticus* (CDC 2005b). Secondary infections occur when injuries are not treated properly and hygiene is poor.

A large part of victims present with contaminated and often superadded infection in wounds (primary infection) after disasters in general. After Hurricane Katrina, the most common illnesses in the weeks following the storms were wound infections skin and wound infections (6.8%) (CDC 2006f). Following windstorms, destruction of infrastructure such as underground pipes may lead to contamination of water lines by sewer lines. In addition, sewer and water treatment plants may be unable to function properly for some time especially if power supply is disrupted. In areas with limited infrastructure and with, for example, open drainage channels the chance of water contamination by fecal material, already high in normal time, is exacerbated after storms when accompanying rainfall wash away material into the common water pool. Poor drainage, common in low-income urban communities of developing countries, leads to chronic problem with water contamination (Parkinson 2003). Often problems linked to infectious diseases after storms emerge because of issues associated to concomitant flooding.

In developing countries, disease surveillance reported a wide variety of outcomes regarding infectious diseases. Outbreaks of acute respiratory diseases, leptospirosis, and cholera have been reported after some storms while in other cases no increase in communicable diseases was reported. Such outbreaks are to be feared in areas where the disease is already present. Occasionally increase of self-limiting gastrointestinal or respiratory infections have been observed (Shultz et al. 2005). Mosquito-borne diseases can increase with an onset-delay after a storm. Increase number of larva habitats and break down of vector control measures are typical causes responsible for the increase.

In all cases active epidemiological surveillance plays a critical role to detect and prevent disease outbreaks when associated with effective field control activities (PAHO 1998). Maintaining adequate sanitary conditions in shelters can be a challenge and conditions may lend themselves to disease outbreaks, especially gastro-intestinal illnesses. The risk of respiratory disease transmission is also elevated due to close proximity of a large number of people. After Hurricane Katrina an outbreak of norovirus gastroenteritis took place among evacuees residing in Houston, Texas and affected over 1000 people or over 20% of adults and 40% of children staying at the facilities (CDC 2005c).

Fecal-oral diseases

Since water pools are mixed after heavy rains and during floods, fecal material may contaminate potable water sources leading to increase in the transmission of diseases such as diarrheal diseases, cholera, typhoid fever and paratyphoid. Compromised sanitary conditions and inadequate sanitary precautions can also cause increased transmission of faeco-oral diseases. Diseases with outbreak potential after a flood include cholera and diseases caused by Salmonella, Shigella, Campylobacter, typhoid/ paratyphoid and viral diseases such as hepatitis A and E and polio in region where it is endemic or where herd immunity is low (Ahern et al. 2005). Outbreaks of diarrheal diseases have been reported numerous times in Bangladesh after floods (Kunii et al. 2002;Schwartz et al. 2006) with specific identification of pathogens including *Escherichia coli*, *Vibrio cholerae* (Qadri et al. 2005), and rotavirus (Ahmed et al. 1991). Qadri et al reported that during the epidemic following the 2004 flood in Dhaka, 22.2% of stools samples collected were positive for *V. cholerae*, 18.0% for ETEC, 3.4% for *Shigella*, and 1.7% for *Salmonella* spp. In areas where diseases with epidemic potential such as cholera are present, the risk of outbreak increase after disasters. A study of patient hospitalized for diarrhea after the super cyclone in Orissa revealed that 80% of them were positive for *Vibrio cholerae* (Chhotray et al. 2002).

In the developed countries, basic public health announcements, regarding drinking water for example, may be effective as most people may be able to implement them. In developing countries infectious diseases are more likely to be on the rise but may not be life-threatening and consequently may not be considered a high priority for public health intervention when dealing within limited resources.

Examples:

- Infectious disease outbreaks are unlikely in developed countries unless water sources are compromised, people are overcrowded and if basic hygiene conditions are not met and sporadic cases are possible. For example two case of toxicogenic *Vibrio cholerae* O1 infection were reported in Louisiana after hurricanes Katrina and Rita (CDC 2006g); they affected patients who had eaten undercooked seafood locally purchased. Non-choleragenic *Vibrio* illnesses were reported in 22 residents of Louisiana and Mississippi after Hurricane Katrina but no epidemic of cholera was identified. Because these bacteria are naturally present in the Gulf of Mexico, such occurrences happen occasionally but disasters increase their frequency. The most common types of illnesses were acute respiratory infections, skin infection/rash illness, and gastroenteritis (CDC 2006f).

- For example after hurricane Mitch that hit Central America in October 1998, Guatemala experienced a serious cholera problem with weekly average of 485 patients after the hurricane compared to 59 before. Nicaragua experienced an increase from 16 patients per week before to 95 afterwards. Belize, Honduras and El Salvador experienced some cholera cases in excess after the storm but to a lesser extend. For leptospirosis, Guatemala, Honduras, El Salvador and Belize reported a number of suspected cases while Nicaragua experienced an epidemic outbreak of 540 cases in the month following the hurricane

- In industrialized countries where public health infrastructure is relatively robust, there is a small risk of increased communicable diseases as sporadic cases but the risk of epidemic is low (Hajat et al. 2005). However failure of water treatment facilities can nonetheless lead to massive outbreaks as was the case with *Cryptosporidium* in Milwaukee, Wisconsin (USA) in 1993 (Hoxie et al. 1997).

Air-borne diseases

Overcrowding and displacement in natural disasters may lead to an increased risk of air-borne diseases, such as ARI, measles and meningitis. It can also facilitate the spread of highly contagious diarrheal diseases, such as cholera or viral diarrheas. Acute respiratory diseases are a common feature after floods. People leaving under crowded conditions are particularly susceptible. In addition measles and meningitis have been shown to increase after floods in specific settings. Respiratory diseases represent a large part of infection reported after disasters, 30 % after the tsunami in Sri Lanka (Ivers and Ryan 2006), 14.5% in New Orleans areas after Hurricanes Katrina and Rita (CDC 2006b), although infectious agents are only rarely identified.

Molds pose a specific problem. They can proliferate indoors after a house has been flooded and it is difficult to get rid of them. This is especially a problem in hot and humid climates. They can trigger or worsen asthma attacks and provoke strong allergic reactions (Ivers and Ryan 2006). After the flooding that took place in the wake of Hurricane Katrina for example, mold was a serious problem with 45.5% of home showing visible mold growth. The higher the flood level in a home, the higher the chance of reporting mold growth was. *Aspergillus* spp. And *Penicillium* spp. were the most common fungus species identified (CDC 2006a).

Respiratory infections are common after disasters and represent a high percentage of people seeking care, as was the case after hurricane Katrina (CDC 2006b) and after the 2004 tsunami in Sri Lanka (Ivers and Ryan 2006).

Vector-borne diseases

Vector- and rodent-borne diseases have the potential to increase after disasters when natural habitats are altered and, very importantly, when implementation of control measures is disrupted. The links between pathogens transmission, vector abundance and environmental conditions such has precipitation, temperature, humidity, soil moisture, and habitats are complex and make it difficult to establish causality. Outbreak of vector-borne diseases have been observed or suspected (Ivers and Ryan 2006) but depend of local conditions and remain difficult to predict.

Several mechanisms can be implicated in outbreaks of vector-borne diseases after floods. One is the increased number of breeding sites increased with more water availability. Such trends are typically observed during the rainy season. Another is that the disaster can disrupt established vector-control measures and lead to an increase of disease cases after a while. Disruption of water supply services may force people to store water in containers that can then become breading place for mosquitoes (e.g. *Aedes*) and lead to increase disease transmission.

Malaria

Although seasonal variations are normal, the transmission is affected by severe weather related floods. Critical parameters like temperature, rainfall and humidity cause increase or a decrease in disease incidence. Post tsunami in South Asia, the rain water diluted the salty waters increasing the favorability for breeding sites and hence a higher occurrence of the disease (Ivers and Ryan 2006). An example of malaria outbreak after a flood disaster occurred in Mozambique in 2000 when the number of weekly cases showed over an eight-fold increase and exceeded the capacity of the local healthcare center (Hashizume et al. 2006).

Dengue fever and dengue hemorrhagic fever (DHF)
The link between dengue and floods is not direct and is still debated. Several studies have investigated this and result often show a possible but not a definitive relationship (Bangs et al. 2006;Wiwanitkit 2006). Causation between environmental conditions and dengue incidence remain elusive denoting the complexity of the overall disease dynamic that includes population susceptibility, immunity, and behavior. For example after hurricane Mitch that hit Central America in October 1998 Dengue, which is endemic in the five countries with nearly 39000 cases reported from January to October 1998, showed a moderate increase in Guatemala and Honduras a month after the storm while malaria incidence was not affected (PAHO 1998). Other vector-borne diseases such as West Nile virus, Japanese Encephalitis, yellow fever, filariasis, and schistosomiasis are also at risk of increasing and should be considered where endemic (Patz et al. 2003).

Rodent-borne diseases
Change in habitats, increased breeding sites or increased contact between humans and rodents may lead to increase transmission of rodent borne diseases. Outbreaks of leptospirosis are typical of post-flood periods particularly in urban slum areas (Ahern et al. 2005;Ivers and Ryan 2006). Urine from rodent carries the pathogen that reaches humans through flood water. This for example has occurred in Jakarta (le Polain de Waroux, personal communication, publication in preparation) and in Brazil in the past few years (Barcellos and Sabroza 2001). A study in four villages affected by the cyclone in Orissa s showed that 14 % of the population was confirmed positive for leptospiroses with another 14% being possible infected (WHO 2000).

3.3.3 Chronic illness and disability

During the flood in Dresden, Germany, in summer 2002, the evacuation of severely ill patients posed logistical problems (Meusel and Kirch 2005). Lack of coordination between crisis management teams lead to hasty evacuation linked to premature deaths in some cases. Additionally, pre-disaster chronic illnesses may be worsened by post disaster conditions, especially medical conditions that need a regular follow-up and a daily treatment and lead to additional mortality. Elderly people seem to be particularly at risk (Mokdad et al. 2005). A study conducted among displaced person sojourning in shelters after Hurricane Katrina showed that over half (56%) suffered from chronic diseases and from these nearly half (48%) lack medication and most common ailments were high blood pressure, high cholesterol, and diabetes (Greenough et al. 2008). Thirty percent were suffering from acute symptoms at the time of admission in shelter and risk factors associated with this condition were concurrent chronic disease, with or lacking medication, and absence of health insurance. An estimated 68% of the medications delivered by pharmacies serving evacuees were for chronic health conditions, among which antihypertensive drugs were the most commonly dispensed drugs after Kartina. (Jhung et al. 2007) After Katrina, special concern was expressed on the urgency of treating patients with diabetes, cardiovascular diseases and kidney diseases (Ford et al. 2006).

Besides persons with lifestyle diseases, most of the HIV patients routinely followed in one of the HIV centers in New Orleans also experienced a 4-to-6 weeks treatment disruption (Infectious Diseases Section of the Louisiana State University Health Science Center 2006).

Apart from access to medication, living conditions also worsen chronic medical problems. Patients with diabetes for example may lack adequate diet, patients with rheumatism or chronic lung diseases can see their symptoms worsened by cold, stress and fatigue, as illustrated in a survey carried out in Japan after the Great Hanshin Earthquake (Mori et al. 2007). Other examples of these chronic medical conditions include cancer, chronic obstructive lung diseases, tuberculosis, asthma, arthritis, anxiety disorders, depression, Parkinson's disease, Crohn's disease, HIV/AIDS, hepatitis B and C (HBV, HCV) (Greenough et al. 2008) Although the burden of chronic illnesses is higher in developed countries and taking care of them may be of higher relative importance there, it is also relevant to consider them in developing countries, as was shown in a post-tsunami survey in Aceh (Guha-Sapir et al. 2007)

In addition to persons suffering from chronic diseases, those with disability require specific attention, notably during the evacuation phase. During flooding people with disability can be particularly at risk if they are unable to evacuate or reach safe ground. Gruesome examples have been reported in Poland, in New Orleans, where motor function impaired patients drowned as flood waters inundated the building where they resided (Kundzewicz and Kundzewicz 2005).Disabilities resulting from mis- management of disaster injuries contribute to the existing burden in the population and create future vulnerabilities particularly after earthquakes given that injuries are a major health impact. No substantial data was obtainable to support the number of mal-union and non-union of fracture cases occurring. The rate of re-surgeries and corrective surgeries has also not been documented. Amputations and spinal paraplegia constitute the main conditions contributing for permanent disability after earthquakes (Roy et al. 2005). Disability as a patient outcome is not adequately addressed in the literature and this is a significant concern (Osaki and Minowa 2001).

3.3.4 Malnutrition

Disasters like floods and windstorms can have direct devastating effects on crops leading to acute food crisis and severely affect the nutritional status of local populations on the medium and long term. Furthermore loss of livelihoods, reduction of income, and disruption of existing economic systems can lead to long-term health conditions due to increased susceptibility to diseases. Emergency and relief teams that typically remain in the field for a few weeks or months provide immediate support after the disaster but do not necessarily stay until the local people have regained their livelihoods. For example in Central America where food availability was already deficient before the Hurricane Mitch, the storm caused a loss harvest of basic grains (rice, beans) planted for domestic consumption estimated between 15% in El Salvador to 70% in Honduras (PAHO 1998). In Honduras evidence of malnutrition triggered by the disaster were detected in children under five 9 months after the disaster (Barrios et al. 2000). In Bangladesh the 1991 cyclone destroyed 60% of cattle, 80% of poultry stock, and 280,000 acres of standing crops leading to food insecurity for the survivors (Shamsuddoha and Chowdhury 2007). Displacement after disasters and compromised food supplies also leads to acute malnutrition after disasters (UNDP 2004). Although Earthquakes do not have direct impact on the crops but disrupted food supplies and livelihoods along with displacement in some cases may contribute to malnutrition.

3.4 Mental Health Impacts

The burden of mental diseases

The mental health problems are disabling and may seriously hinder individuals to resume their course of life. At the individual level, mental health problems may disable functioning in various domains of daily life (cf. (American Psychiatric Association 2000)). For instance, mental health problems may hinder work performance, or participation in social and leisure activities (American Psychiatric Association 2000;World Health Organization 2001). At a community level mental health problems are likely to encumber the post disaster reconstruction of society.

In the Global Burden of Disease study (Murray and Lopez 1996) introduced a measure comprising both years of life lost to premature death and years lived with a disability on a population ('disability adjusted life year' [DALY]), allowing for comparison between different diseases. They revealed that neuro-psychiatric disorders constituted 10.5 percent of the total burden of disease, proportionally increasing to 15 percent in 2020. The DALY figures on mental health are extremely high when compared to individual diseases such as malaria that constitutes 2.6 percent or cancer that comprises 5.8 percent of the global burden of diseases. When disregarding premature mortality and merely focusing on disability (Murray et al. 2002), it was estimated that 31 percent of all years lived with disability worldwide is caused by psychiatric disorders (Murray et al. 2002;World Health Organization 2001). In the extreme circumstances of the post disaster situation the prevalence of psychiatric and psychological symptoms are higher than in the 'normal' situation. Thus absolute disability figures are likely to be elevated (De Jong 2002). Despite these extreme disability figures underscoring the significance of mental health problems, the lethal non-mental diseases continue to command the majority of the attention (De Jong 2002).

Direct impact

During the emergency phase of a natural disaster, physical health problems are often accompanied by a variety of psychosocial and mental health problems. Individuals and communities repetitively exposed to natural disasters are particularly at risk. Recurring disasters may increasingly deplete resources, so individuals and communities end up in negative spiral of loss from which it is difficult to recover (De Jong 2002).

Numerous studies on earthquakes, cyclones, floods, volcano eruptions, land slides and avalanches in Europe, Asia, Oceania, and the Americas revealed a broad range of psychosocial and mental health problems in the aftermath of the disaster. We will distinguish psychosocial, psychological and psychiatric symptomatology, of which psychosocial symptoms are most common and psychiatric disorders are least common[1].

First, the psychosocial problems in the wake of a natural disaster are rife. In the wake of natural disasters studies reported increased looting, discrimination (Weems et al. 2007), behavioral problems among children (Norris et al. 2002) (Swenson et al. 1996), increased domestic violence (Solomon and Green 1992;Young et al. 1999), increased alcohol, drug and cigarette abuse (Leon 2004;Norris et al. 2002;Schroeder and Polusny 2004;Young et al. 1999). These psychosocial problems are the province of social interaction and may severely disrupt the social fabric of society in the wake of disasters.

[1] For the readability of the text, the psychosocial, the psychological and the psychiatric consequences of natural disasters and their numerous corresponding references are summarized in Table 1 in Appendix 2.

Second, there is general consensus in the disaster literature that the majority of disaster victims experience one or more psychological symptoms, e.g. (Leon 2004). The psychological consequences found in the wake of natural disasters are wide-ranging: severe emotional distress, anxious feelings and thoughts, bereavement, survivor guilt, somatization, irritability, sleeping difficulty, hopelessness, temper outbursts, worrying, feeling critical of others (tabulated in Appendix 2). Experiencing one or more symptoms in the immediate aftermath of a disaster is the rule rather than the exception and seems to be normal. Most symptoms naturally abate over time. However, in a small proportion of the disaster affected population symptoms may persist over time and become pathologic if left unattended.

Third, particularly worrying is the development of psychiatric disorders of disaster victims. The most common mental disorders found among populations exposed to natural disasters, were posttraumatic stress disorder (PTSD) (American Psychiatric Association 2000), depression and anxiety disorders (tabulated in Appendix 2). Research revealed that the prevalence rates of psychiatric disorders among populations exposed to a natural disaster are substantially higher than observed in the general population; see for other reviews: e.g. (Norris et al. 2002;Norris 2002) (Solomon and Green 1992) (Gibbs 1989). On the basis of the results of many studies one could conclude that natural disasters collectively traumatize a vast proportion of the exposed population. These findings seem to reflect the post disaster reality. Prevalence rates of full-blown psychiatric disorders generally vary from just over 10 percent to approximately 40 percent (see Table 13 for references).

Table 13: The psychosocial, psychological and psychiatric consequences of natural disasters and their corresponding references

Symptoms	References
Psychosocial symptoms	
Behavioral problems among children	(Norris et al. 2002;Swenson et al. 1996)
Increased domestic violence	(Solomon and Green 1992;Young et al. 1999)
Increase in the use of alcohol, cigarettes or drugs	(Leon 2004;Norris et al. 2002;Schroeder and Polusny 2004;Young et al. 1999)
Psychological symptoms	
Psychological/emotional distress	(Benight et al. 1999;Kaiser et al. 1996;Murphy 1988;Norris et al. 2002;Sattler et al. 2006;Smith and Freedy 2000;Solomon and Green 1992;Souza et al. 2007)
Depressed affect	(Cook and Bickman 1990;Freedy et al. 1994;Goenjian et al. 2000;Najarian et al. 2001;Norris et al. 2002;Souza et al. 2007)
Anxious feelings and thoughts	(Cook and Bickman 1990;Freedy et al. 1994;Goenjian et al. 2000;Swenson et al. 1996;Young et al. 1999)
Bereavement	(Solomon and Green 1992)
Survivor guilt	(carballo et al. 2006)
Somatization	(Cook and Bickman 1990;Leon 2004;Lutgendorf et al. 1995;Murphy 1988;Norris et al. 2002;Young et al. 1999)
Irritability	(carballo et al. 2006;Freedy et al. 1994;Norris et al. 2002)
Sleeping difficulty	(carballo et al. 2006;Freedy et al. 1994;Norris et al. 2002)

Hopelessness	(Freedy et al. 1994)
Temper outbursts	(Freedy et al. 1994)
Worrying	(Freedy et al. 1994)
Feeling critical of others	(Freedy et al. 1994)
Suicide	(Leon 2004;Norris et al. 2002)
Psychiatric disorders	
Postraumatic stress disorder (PTSD)	(Adams and Boscarino 2006;Basoglu et al. 2002;Basoglu et al. 2004;Bödvarsdóttir and Elklit 2004;Bokszczanin 2007;Catapano et al. 2001;David et al. 1996;Gibbs 1989;Goenjian et al. 2000;McMillen et al. 2000;Neuner et al. 2006;Norris et al. 2002;Norris et al. 2004;Sahin et al. 2007;Soldatos et al. 2006;Solomon and Green 1992;Suar et al. 2002;Ticehurst et al. 1996;Tural et al. 2004;Weems et al. 2007;Young et al. 1999)
Depression	(Basoglu et al. 2002;Basoglu et al. 2004;Briere and Elliott 2000;David et al. 1996;Gibbs 1989;Goenjian et al. 2000;Norris et al. 2002;Norris et al. 2004;Sattler et al. 2006;Solomon and Green 1992;Souza et al. 2007;Suar et al. 2002;Watanabe et al. 2004;Young et al. 1999)
Anxiety	(Briere and Elliott 2000;David et al. 1996;Gibbs 1989;Goenjian et al. 2000;Norris et al. 2002;Solomon and Green 1992;Suar et al. 2002;Young et al. 1999)

The experience of peri-traumatic stress ((Basoglu et al. 2002;Basoglu et al. 2004;Tural et al. 2004)), peri-traumatic dissociation ((Soldatos et al. 2006) (Halligan and Yehuda 2000)) and acute posttraumatic distress ((Sattler et al. 2006;Soldatos et al. 2006) (Benight et al. 1999)) are risk factors for the development of psychiatric syndromes. Natural disasters victims often suffer from a combination of psychiatric disorders at a rate that exceeds chance, termed co-morbidity. Studies demonstrated co-morbidity of PTSD with depression among a substantial proportion of elderly earthquake victims in Turkey (Cagri et al. 2006), flood victims in the USA (North et al. 2004), flood and mudslide victims in Mexico (Norris et al. 2004), and hurricane victims (David et al. 1996). (Goenjian et al. 2000) documented that posttraumatic stress, anxiety and depressive reactions were highly correlated among Armenians exposed to an earthquake.

Psychological and psychiatric symptoms over time

Due to scarcity of longitudinal research it is difficult to draw conclusions on whether psychological and psychiatric symptoms or syndromes persist. The majority of the disaster research supports that 'time heals wounds', i.e. most psychiatric disorders and symptoms abate naturally in time (Sahin et al. 2007) (Lewin et al. 1998;Solomon and Green 1992;Young et al. 1999). However, Norris et al. (Norris et al. 2004) documented that post traumatic stress symptoms initially declined but subsequently stabilized among flood and mudslide victims in Mexico. Briere and Elliot (2000) (Briere and Elliott 2000) documented that among the US population exposed to natural disasters, previous disaster experience was associated with significantly higher scores on posttraumatic stress symptoms, even though the time from the last disaster to involvement in the study was 13 years on average. Co-morbid disorders were found to last more persistently than single occurring psychiatric disorders (North et al. 2004).

4. Health Care System Impacts

The impact of natural disasters on the health care system are two fold- direct impact on the health care infrastructure, for instance structurally damaged buildings, inadequate qualified staff and lack of supply during and in the aftermath of the disaster and secondly the inability to cope with additional demand on hospital services because of injuries, disease outbreaks, etc. The intensity and the time frame of the impact on the health care system depend largely on the nature of the natural disaster.

Primary failures of health care centers due to structural damage are a serious problem. The most vulnerable population in the society is housed in the hospitals twenty four hours (PAHO 2005). The evacuation of these is a daunting task in cases of infrastructural damages. In Dresden Germany in 2002 four of the six major hospitals in the city lost power and had to be evacuated and was an enormous logistical challenge (Meusel and Kirch 2005). Death of health care staff as a direct impact of disaster is also a challenge especially after earthquakes. The destruction of health care facilities makes the early management of injuries difficult.

Most secondary failures result mainly from the exhaustion of supplies and staff burn out. Systemic failures prevent the much required early management of the injured. Such conditions represent a burden that can affect emergency care, drug procurement and interrupted vertical disease control programs and overall make the public health response more difficult. Disasters, especially flooding can have long term secondary effects, such as disruption of vaccine, maternal-child health, and tuberculosis public health programs (Ahern et al. 2005;Ivers and Ryan 2006). Punctual interventions, such as immunization campaign, may provide a much needed public health boost. Data about the use of health services after disasters are scarce and have not been extensively investigated, at least in Europe (Hajat et al. 2005).

As a result of primary or secondary failures, baseline medical emergencies that are encountered throughout the post disaster phase even on day one are a challenge. These include routine gynecological conditions and surgical emergencies like appendicitis as well as accident and trauma cases. Most medical conditions reported are diseases exaggerated due to lack of required medications or their use most common being diabetes, hypertension, chronic obstructive pulmonary disease (COPD), tuberculosis (TB) as well as system failures that lead to accumulation of the routine work load (Riddez 2007). Increased incidence of stress related diseases like the peptic ulcers and ischemic heart diseases have also been recorded (Roshchin and Mazurenko 2002). Soon after the disaster outside help may be able to fill the gap and provide immediate care.

Figure 4 schematizes the need and use of hospital resources after a time-point disaster such as an earthquake. Immediately after the event (phase 1), there is immediate and high demand for trauma-related surgery and care above the baseline of medical emergency. After a week or so (phase 2), emergency needs subside but the hospital deals with handling trauma complications. Simultaneously (phase 3) non-trauma emergencies (e.g. infectious disease, treatment of chronic diseases) increase; they are related to destruction of infrastructure or disruption of health care system. Finally in phase 4 there is an increase of elective care needs that have been postponed due to the disaster.

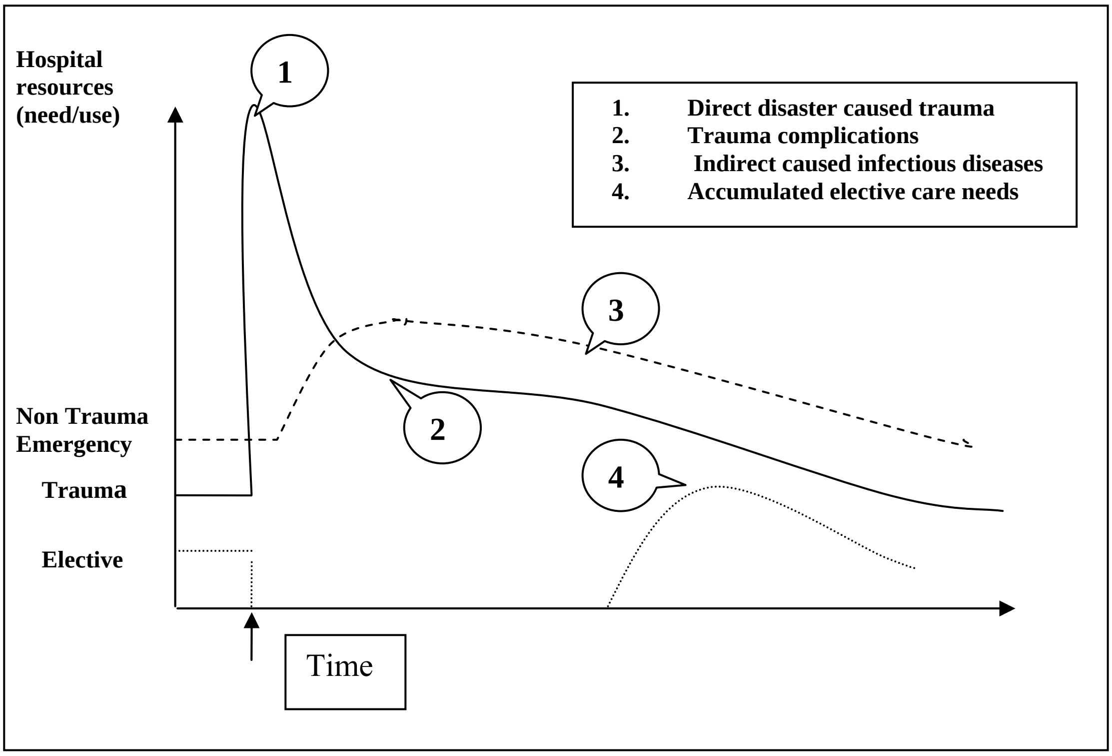

Figure 4: Conceptual variation of needs/ use of hospital resources before and after a disaster. Modified version adapted from (Riddez 2007)

Access to health care is a challenge following all disasters. After Hurricane Katrina a study compared treatment accessibility for pediatric and adult patients with sickle cell disease (Karras and Hemenway 2007) and found that patients, predominantly adults, who relied on New Orleans main public hospital experienced increased frustration and dissatisfaction compared to the situation before the hurricane whereas patient, predominantly pediatric, having access to private facilities had access to similar level of care before and after the disaster. Thus, patients with limited options in their choice of health care are at greater risk to suffer worsened health condition. When public hospitals are impacted by a disaster the poor are more likely to be disproportionally affected in the long term in the aftermath of the disaster.

5. Conclusion

5.1 Evidence overview

Table 14 gives an overview of the disaster impacts on health and health systems. Storms and floods are pooled because impacts are often similar while earthquakes have unique features with corresponding specificity on the health of the population.

Table 14: Summary of health impacts after disasters (modified from (del Ninno et al. 2001;Few 2007))

Health Impact	Floods/Windstorms	Earthquakes
Mortality	Impact deaths due to drowning: higher in flash-floods and coastal surges than in slow rising riverine floods. Secondary causes of death: CO contamination, worsening of chronic diseases, (infectious diseases, injury, suicide).	Impact deaths higher than secondary deaths. Primary causes of death include serious head, chest, abdominal, and crush injuries.
Injury	Collapse of shelter, contact with submerged objects/flying debris, vehicle accidents	Falling debris/building material, falling objects, heavy furniture, entrapment and crush injury, falls during escape, vehicle accidents
Infectious Diseases	**Oral-fecal and water borne diseases** Contamination and Disruption of water and sanitation systems Reported examples : cholera, salmonella, shigella, campylobacter, enteroviruses, typhoid, paratyphoid, hepatitis (A/E)	Source contamination less likely. Possible systemic disruption of water and sanitation systems. Reported examples include: diarroheal diseases.
	Vector/Rodent Borne Diseases Altered breeding conditions. Increased human contact with rodents and hence rodent borne diseases such as leptospirosis.	Rodent borne disease a possibility, no direct effect on vector breeding however interruption of vector control programmes alters disease transmission.
	Air Borne Diseases Dampness and mould in houses. Exposure to cold weather due to dislocation and overcrowding in emergency shelters. Reported examples: ARI, measles, meningitis,	Exposure to cold weather due to loss of shelter especially children and due to overcrowding. Reported examples: Flu and Pneumonia, Exaggerated COPD
Chronic diseases	Systemic Interruption and lack of access to drugs.	Systemic Interruption and lack of access to drugs.
Malnutrition	Crop damage, loss of subsistence food, reduced consumption, disruption of food supply, livelihoods and income	Disruption of food access to supplies, livelihoods and income
Health Risks and chemical contamination	Exposure to water and pathogens within, population displacement and overcrowded shelters, contaminated drinking water sources and lack thereof, inadequate sanitation facilities and practices.	Crush injuries, suffocation, fires following earthquakes, population displacement and overcrowding, destruction of water and sanitation infrastructure

It is apparent that earthquakes are high impact disasters with primary deaths accounting to most mortality. Very little information is available about the exact cause of death after earthquakes primarily due to the difficulty of conducting autopsies on a case to case basis. Injuries are responsible for a large part of morbidity after earthquakes. The injury epidemiology data reported in the studies needs to be interpreted with caution as majority of the studies reviewed single hospital data. Drawing generalized conclusions from them should be avoided even if they are pragmatic substitutes for unfeasible population based studies to obtain disaster data. There is little information documented about the causes of injuries. Better investigation of the factors responsible for morbidity and mortality may assist in effective prevention and mitigation strategies.

The most important aspect in earthquakes from the health care systems point of view is the primary failure due to structural damage and delayed secondary failure due to exhaustion of supplies. Health care system strengthening for immediate surge capacity and resiliency especially in earthquake prone areas is therefore mandated. There is little evidence base for incidence and transmission of communicable diseases after earthquakes. Given that public infrastructure may be at the risk of destruction after a large impact event such as an earthquake, the impact of parallel systems dysfunction such as water and sanitation, communication and transport on health needs further attention.

Windstorms present unique health challenges due to the violence, destruction and extent of the events. Unlike earthquake, however, forecasting is now possible with much better accuracy than in the past making early warning and evacuation possible. This has help reduced the number of casualties especially in develop countries. In developing countries the benefit of early warning system is still impeded by lack of resources to implement effective response, increased population living in risk-prone area. Table 10 summarizes the health risks linked to windstorm in function of disaster phase and hazard.

Nonetheless, there is still lack of data about the health status and the heath needs among survivors an people displaced by the disaster (Greenough et al. 2008). This is particularly true for minorities and migrants, often of low social status and limited income, who may not be able to benefit from government interventions (Chen et al. 2007) (Messias and Lacy 2007). Infectious disease outbreaks are difficult to report in a systematic manner. In developing countries in particular such reports emerge only from sporadic studies (Chhotray et al. 2002) (WHO 2000) as surveillance data are weak or inexistent.

There is a need for population-based statistics to identify groups at risk (Combs et al. 1993) and a need for standardization to optimize public health response. Even within a single developed country, the United State, one of the major challenge after Hurricane Katrina was to integrate surveillance data that was collected at different levels (hospital, state and local jurisdiction) and lack of standardization in term of reporting forms and condition assessed (CDC 2006c). There is a great need to develop standardized morbidity surveillance tools. Although the general risks and impacts of windstorms are well documented, most publications concern the North and Central America (Table 4). The US scientific community and the Centers for Disease Control and Prevention (CDC) in particular play a leading role in this regard. The aftermath of hurricanes Katrina and Rita that affected the US Gulf Coast in a striking manner received an enormous amount of attention in the scientific literature. In contrast publications regarding Asia are scarce or not available in the English scientific literature. Specifically there seem to be a lack active surveillance after disaster in Asia or it is not well reported. This leads to a knowledge gap regarding the specific local needs in the various Asian countries affected by tropical cyclones and limit the efficacy of public health intervention to respond optimally to the specific needs of affected populations.

Floods represent a variety of health challenges ranging from injuries and infectious diseases, to logistics issues regarding treatment supply for chronic diseases. If large outbreak of infectious diseases are not common in developed countries (Vasconcelos and the Unit for Preparedness and Response 2006), surveillance is important to respond to sporadic cases and prevent further infections. This is even more critical in developing countries endemic diseases can flare up after disasters. Local conditions should be taken into account and knowledge about disease baseline is essential to remain vigilant about potential disease outbreaks and to prepare effective public health response.

Despite a large body of literature on floods, specific clinical information about flood-related morbidity and injuries is scarce (Ahern et al. 2005). As is the case after storm disasters, the needs of population after floods are not well documented. The challenge is great however because the need for surveillance should not interfere with the need to provide immediate care and identification of specific pathogens, causing diarrheal diseases for example, is often not practical.

To advance on the traditional disaster literature, research should move beyond the mere documenting of the psychosocial and mental health problems subsequent to natural disasters. Evaluating the underlying individual and community level processes of mental health deterioration in the disaster setting, will render valuable insight in risk and protective factors of individuals and vulnerability and resilience of communities. Within the MICRODIS project, the individual and communal trajectory of mental health deterioration is the province of the Social Group, constituting a basis for integration between the Social and the Health Group. These underlying factors will yield valuable input for post disaster interventions.

Destruction of supportive infrastructure

A common feature of many disasters is the subsequent destruction of infrastructure such as transport links (roads, bridge, and train-tracks), water and sanitation system, power and gas supply. Such disruptions bring about a number of predictable health issues that are to be expected after any disaster.

These are:

- “fecal-oral" infections, especially diarrheal diseases, due to the disruption of water supply system and/or sewage systems.
- Carbon monoxide (CO) poisoning due to the lack of electricity and the use of electricity generator under inadequate ventilation conditions.

In addition, full or partial disruption of health facilities (hospital, etc) limits the possibility of effective care.

Disruption of communication system (radio, TV) exacerbates possible difficulties of the relief effort. Food supply can become an issue in remote areas, especially when needs cannot be communicated effectively.

5.2 Existing knowledge gaps

As was the case in the floods in the UK, it is often assumed that problems are over once the acute phase of the disaster has passed and people have returned to their homes. The emergency phase may be over after a few days or weeks but for the affected population the “return to normality” may take months or years. Dealing with loss of love ones, loss of property and memorabilia, life-altering events such as injury or disability, loss or change of livelihood is a long-term process that is not well studied.

Few studies consider **mid-and long-term** consequences of disasters in term of health impact and health care systems.

It has been a difficult task to quantify the risk and burden of infectious diseases after disasters. Outcomes are inconsistent and highly dependent of specific circumstances. Active surveillance helps keeping track of developing outbreaks but there are no universal tools.

Although mental health has been recognized as an important issue in the aftermath of disasters, most studies have taken place in developed countries. **Mental health** aspects have been rarely studied in **Asian countries** and a few publications from Bangladesh, Sri Lanka, Indonesia, China, Korea, India and the Philippines (e.g. (Kar et al. 2007;Kar and Bastia 2006)) appeared only recently. Tools must be adapted to the local cultures and methods developed in western countries may be inadequate and ineffective in Asia. Experience after the 2004 tsunami suggests this. The development of systematic scientific research on these issues in Asia is still very recent and warrants special attention in future research in the field of disaster management.

Although there is growing evidence that **chronic disease and disability** create a great burden during and in the aftermath of disaster, these shortcomings are not well documented, and reporting is mostly anecdotal. There is currently a lack of knowledge and information about the burden of natural disaster on chronic health problems. Most of the examples come from the experience in Katrina, with the specific characteristics of Louisiana, and further studies should be carried out in other countries and other natural disasters. In addition, more research in needed about the health prospect of people who have become disabled because of a disaster injury.

Impacts on **health care systems** and their recovery after disaster in term of structure, service, and personal is not well studied. The quality of data is an essential point to consider.

5.3 Perspectives for the MICRODIS project

In view of this review and considering the scope of MICRODIS it may be interesting to:
-develop good tools for evaluating the burden on **chronic health problems** of the natural disasters, as it may give a first evidence about that issue in Asia and Europe, and has many public health implications.
-study the "fate" of people who became **disabled** because of a disaster
-focus on **vulnerable groups**
-take **mental health** into consideration
-consider **health care system** response and capability, surveillance as well as quality of data through health information system (HIS) and health and management information system (HAMIS)

Although there is some overlap regarding health needs after a disaster, there are clear differences between developed and developing countries that are likely to lead to a different set of priorities in the aftermath of a disaster.

Studies in Europe may want to emphasize:
-mental health aspects in medium and long term
-chronic diseases
-disability

-vulnerable groups in particular poor and migrants
-health care systems: recovery, change in emergency planning, disease surveillance

All these aspects are also important and relevant in Asia, in addition the following aspect may be considered with added focus:
-potentially life-threatening infectious diseases
-gender specific issues
-vulnerable groups: poor, migrants, socially excluded
-health care systems: availability, accessibility, quality and coverage over an area, service, capacity, recovery, emergency planning, disease surveillance

Appendix 1: Glossary

Disaster: a situation or event, which overwhelms local capacity, necessitating a request for national or international external assistance (CRED 2008b).

Earthquake (USGS 1994): An earthquake is defined as “a sudden movement of the earth, caused by the abrupt release of long accumulated strain from within the Earths crust”.

Flood (USGS 2007): Flood may be defined as “An overflow or inundation that comes from a river or other body of water and causes or threatens damage. Any relatively high stream flow overtopping the natural or artificial banks in any reach of a stream” Flash flood is a result of heavy or excessive amounts of rainfall within a short period of time, usually less than 6 hours, causing water to rise and fall quite rapidly.

Hazard: threatening event, or probability of occurrence of a potentially damaging phenomenon within a given time period and area (CRED 2008b).

Windstorms: Windstorms are atmospheric depressions (low pressure systems) that generate strong winds and can displace large amount of sea water onto land (storm surges) in coastal areas (World Meteorological Organization 2008). They include:
-Storm (CRED 2008b) : Wind with a speed between 48 and 55 knots = 88-100 km/h.
-Tropical cyclone (National Hurricane Center 2008): a generic term for a low pressure system accompanied by thunderstorms that usually forms in the tropics. Depending upon intensity, tropical cyclones are called tropical depressions, tropical storms, or cyclone/hurricane/typhoon according to their geographical location (see Table A1).
-Tornado (CRED 2008b): Violently rotating storm diameter; the most violent weather phenomenon. It is produced in a very severe thunderstorm and appears as a funnel cloud extending from the base of a cumulonimbus to the ground.
-Winter storm: Snow (blizzard), ice or sleet storm: Winter storms are not considered in this document.

Table A1: Classification of cyclone intensity on the Saffir-Simpson scale (Shultz et al. 2005)

Stage (*Regional name* **and Region)**	**Maximum Wind speed***	**Storm surge (level above normal)**	**Central Pressure**	**Expected damage**
Tropical depressions	<33 knots; <61 km/h			
Tropical storms	34-63 knots; 62-117 km/h			
Tropical cyclone: generic designation **(Cyclone**: Indian Ocean; South Pacific) **(Hurricane**: Atlantic Ocean; Caribbean; Gulf of Mexico; Eastern North & Central Pacific) **(Typhoon**: Western North Pacific; South China Sea)	>64 knots ; >118 km/h			
Category 1	64-82 knots 119-153 km/h	1.2-1.8 m	≥980 Mbar	-no real damage on bu -some damage on veg -minor pear damage
Category 2	83-95 knots 154-177 km/h	1.9-2.7 m	965-979 mbar	-roofing, door, windo -considerable damage
Category 3	96-113 knots 178-209 km/h	2.8-3.9 m	945-964 mbar	-some structural dama -coastal flooding
Category 4	114-135 knots 210-249 km/h	4.0-5.5 m	929-944 mbar	-some roof structu residences -Major erosion on bea
Category 5	>135 knots >249 km/h	>5.5 m	<920 Mbar	-Many roof failure buildings -Major flooding

* 1 knot = 1.852 km/hr

Appendix 2: Chemical contamination– Full text

(Written by **Marita Luotamo** and **Kai Savolainen**, Finnish Institute of Occupational Health)

Globally there are over 100 000 chemicals in different uses in different industrial sectors including large scale industries and small and medium size enterprises, agriculture including professional and home scale activities, and gardening. The uses of chemicals also include cleaning and disinfection, at public institutions and at homes, and other uses such as the production and distribution of pharmaceutical products. Practically, nearly all consumer products have either been made out of chemicals or are chemicals such as plastics, paints and lacquers which are mixtures of chemicals. Several hygienic and cosmetic products are also chemical mixtures. Thus, chemicals are present everywhere in societies and communities; although there are huge differences in the used volumes of different types of chemicals used and in the diversity of different chemicals in terms of their toxicities.

There are many different ways of using, storing, transporting and discharging of chemicals and chemical-containing products, which is crucial in areas where flooding is possible. Chemicals have not so far been in any specific focus when the impacts of floods have been evaluated. The aim of this review is to analyze, based on the information available in the literature, the sources and roles of chemicals in floods in different parts of the world.

Past experiences of floods and chemicals

Chemicals may be released into the floodwater from industrial, agricultural and domestic stores. Chemicals may also contaminate the floodwater during their whole life-cycle from production to use, recycling and discharging as well as during transportation.

Floods may have multiple environmental consequences which may affect the public health directly or indirectly. These effects potentially include direct contamination of homes and other buildings, contamination of drinking water sources either by infectious or chemical materials and disruption of sewage systems, both residential and industrial. Chemicals may be released from storages, e.g. underground fuel tanks, or by remobilization of chemicals already present in the environment such as metals and pesticides. Flooding can potentially increase the amount of chemicals which run off from farms, lawns, and streets into rivers, lakes and coastal waters (Euripidou and Murray 2004).

One source of chemical leaks in floods is the alluvial aquifers used in vertical and horizontal collector wells as important components of drinking water production. Ray et al (Ray et al. 2002) studied the river bank filtration (RBF) when permeable river bed and underlying aquifer solids are used to diminish dissolved and suspended contaminants through physical filtering, sorption and degradation. Dilution of the contaminants is also possible if the concentrations are lower in the ground water that the surface water. RBF have been widely used in Europe and United States for public and industrial water supplies.

USA - New Orleans - Hurricane Katrina

Although Katrina is classified as Hurricane, enormous flooding was one of the long lasting effects of this one of the most devastating hurricanes of recent years. United States Environmental Protection Agency US EPA) and Centers for Disease Control and Prevention (CDC) have studied the possible effects of floods including the chemicals. The key-questions raised regarding human health effects of flooding associated with Hurricane Katrina were closely linked with the fundamental environmental issues addressed in the initial evaluation report by US EPA and CDC (EPA and CDC 2008). The team identified the key issues and supporting infrastructure to be included in the initial assessment: drinking water, wastewater, leaks of solid waste/debris, evoked contamination of sediments and soil with toxic chemicals. Important issues were also production of energy, dealing with natural gas pipelines and protecting houses from flood water. Occupational and public safety and health and security, rodent/animal control, maintaining functional roads, and assuring the integrity of underground storage tanks containing e.g. gasoline and food safety were included in the list. Occupational safety and health as well as public security was identified as cross-cutting all the other areas (EPA and CDC 2008).

After Katrina hurricane, 60-80% of New Orleans city on the east side of Mississippi River was under water, and in some locations flood waters were over thirty feet deep (EPA and CDC 2008;Roper et al. 2006). The flood water was pumped to Lake Pontchartrain and Mississippi rivers. In the heat and stagnation, the waters became heavily polluted with petroleum products such as gasoline from underground tanks, industrial chemicals, raw sewage, and dead animals (Roper et al. 2006). Pardue et al (Pardue et al. 2005)) found elevated concentrations of Pb, As and Cr many of which some cases exceeded the levels of drinking water standards. The results indicated that Katrina floodwater is similar to normal storm water runoff but with somewhat elevated Pb and volatile organic chemical (VOC) concentrations. The absence of major toxic contaminants was explained by several factors. These included dilution and pH of water. Because of the alkaline pH of the flood water the lead in car lease-acid batteries was not leached into the environment in any larger quantities. Alkalinity also attenuated evaporation of lead compounds in addition to chelating the lead-containing compounds that together diminished reduced leakage of lead into the environment. Pardue et al (Pardue et al. 2005) though collected samples in areas in New Orleans where no chemical factories were situated. The authors concluded that more studies are needed concerning environmental exposure before one can draw any definite conclusions.

Huge quantities of the floating debris were estimated to be removed and managed and some of these materials were regarded hazardous. For example, small colloidal particulates that are suspended in the water included organic contaminants, metals and disease-causing micro-organisms. Contamination of the soil and sediments was possible because the releases from chemical plants, manufacturing facilities, refineries, homes and other buildings (EPA and CDC 2008;Roper et al. 2006). Over one hundred priority pollutants, such as VOCs, semi-volatile organic compounds (SVOCs), total metals, pesticides, herbicides, and PCBs were analyzed. Lead was the pollutant most often found in the samples and the pollutant that most frequently exceeded the US EPA standard. The locations in which high lead concentrations were found, were know historically high in lead content.

One class of the analyzed hazardous organic compounds was divided into the following categories: 1) polyaromatic hydrocarbons (PAHs) found in petroleum and coal tar products; 2) polychlorinated biphenyls (PCB); 3) pesticides; and 4) miscellaneous chemicals. Study concluded that the floodwaters redistributed some chemical toxicants, but the contaminant burden in soils and sediments generated fewer that previously assessed concerns for acute exposure and risk of chemicals. One of the local risks was the impact of a crude-oil tank failure. One of the most serious continuing risks has been the presence of high concentrations of molds, bacteria, and airborne mold spores in moisture-damaged structures causing allergies and asthma among many of the exposed (Roper et al. 2006).

Schwab et al (Schwab et al. 2007) published a study conducted in New Orleans on the indicators of bacterial contamination, contamination by airborne molds or surface molds and their spores, and sediment and soil samples for lead (Pb) and arsenic (As) in flood water samples. The samples were collected in three regions of the flooded area between September 15 and October 12-14, 2005. Results showed high bacterial contamination of the surface waters as assessed by bacterial indicators of the large volumes of human waste with an origin is the sewer system of a large metropolitan region. Elevated Pb and As concentrations in soils are indicators of anthropogenic activities and are often due to cumulative deposition that may cause a risk for communities from hazardous environmental exposures. Airborne and surface molds also created a higher risk to citizen's risks of who was also verified in the study.

Ambient concentrations with passive sampling of VOC were measured in the Greater New Orleans in the aftermath of Hurricane Katrina. About 30 different organic compounds were determined including benzene, toluene, ethyl benzene, carbon tetrachloride, styrene, naphthalene, trichloroethylene, tetrachloroethylene, and chloroform, and the overall results suggested rather low concentrations of various contaminants (Chung et al. 2006)

Hurricane Katrina caused a landslide on the Louisiana peninsula, Adams et al (Adams et al. 2007) conducted a study to determine the concentrations of leachable inorganic and organic constituents in sediments and associated soils (altogether 46 samples) in New Orleans after the floodwaters had been removed. Out of the analyzed inorganic components As and Pb concentrations exceeded drinking water standards, while the other metals Cd, Cr, Cu, Hg and V showed much lower leachable levels. Benzene, most likely representing gasoline constituents, was detected over the limit of detection and the 18 analyzed pesticides were below the limit of detection. (Adams et al. 2007) The authors concluded that there is a need for another study to explore the presence of heavy metals bound to soil and that are not readily leachable.

Van Metre et al (Van Metre et al. 2006) studied the effects of Hurricanes Katrina and Rita by analyzing the samples of street mud and suspended and bottom sediments. In the bottom sediments elevated concentrations of Pb, Zn, polycyclic aromatic hydrocarbons (PAHs) and chlordane. The levels of those chemicals exceeded their median concentrations in U.S. urban lakes and guidelines for lake sediments. The authors concluded that the effects of Hurricanes Katrina and Rita on the sediment chemistry of Lake Pontchartrain are limited spatially and are most likely transient.

USA - Minnesota River

Elevated methyl mercury concentrations and loadings during flooding in the Minnesota Rivers were determined after the major flooding episodes in the summer of 2002, when frequent intense precipitation events resulted in extraordinarily wet conditions in East-Central and North-Western Minnesota. (Balogh et al. 2006) The authors concluded that when flooding and wet conditions in this region increase in parallel, the production of MeHg and its leaching from terrestrial areas to surface waters will also increase.

Honduras - flood following the Hurricane Mitch

In October 1998 the Atlantic tropical storm Mitch upgraded to hurricane being one of the strongest having ever hitting Central America. When the hurricane was in Honduras, it caused catastrophic floods and mud slides throughout the country (Balluz et al. 2001). The flooding increased the potential for environmental contamination by toxic chemicals from toxic waste sites, and chemicals stored at ground level. Especially, pesticides and other agricultural chemicals can be flushed into residential areas and rivers causing environmental contamination. Balluz et al (Balluz et al. 2001) evaluated the chemical contamination of potable water and the extent of human exposure to chemicals as a result of the flooding. In this study, water samples were analyzed and biological monitoring analyses of serum specimens were carried out for DDT and organophosphate metabolites. There was significant contamination of soil, but no water contamination. The soil levels of chlopyrifos and parathion were 30- and 1000-times higher, respectively, than Environmental Data Quality Level. Elevated levels of chlorinated and organophosphate pesticides in adolescents were most striking. Elevated levels were found even three weeks after the hurricane, which in case of these substances with short half lives an ongoing threat of exposure have been possible for longer time. In the biomonitoring results elevated levels were found in serum p,p´-DDE (metabolite of DDT), dieldrin, organophophate metabolites, diethyl phosphate, para-nitrophenoland 3,5,6-trichloro-2-pyridinol. The authors concluded, that the elevated concentrations of organophosphates were surprising because these substances were banned in Honduras already 15 years ago, which actually shows that those substances were still used in Honduras. In the survey, the most common self-reported symptoms were headache (44.4%), tiredness and weakness (42.2%), skin rash (40%), abdominal pain (33.3%), fever (27.7%), decreased appetite (24.4%), chills (22.2%) and nausea (22.2%) - more frequent in adolescents than in adults (Balluz et al. 2001).

Canada - Mackenzie Delta

Canada's longest river, the Mackenzie River, empties into the Beaufort Sea in a region known as the Mackenzie Delta. The Mackenzie Delta is the largest delta in Canada and the twelfth largest delta in the world. Its watershed drains five provinces or approximately twenty percent of Canada. Two hundred and ten kilometers in length with an average width of sixty-two kilometers, the Mackenzie Delta covers an area of 13,500 km^2 and contains approximately 25,000 lakes (http://www.bmmda.nt.ca/mackenzie_delta.htm).

Headley et al., published the results of PAH concentrations in lake sediments and concluded that for some lakes, the concentration of PAHs decreased with decreasing flooding frequency and decreasing sedimentation rates.(Headley et al. 2002) PAHs appear to be more consistent with biogenic and pyrogenic origin, and the overall PAH budget petrogenic source appears to be dominant.

Europe - flooding in the UK

Health Protection Agency (HPA) in the United Kingdom has reported significant flooding in England in 2007 in Yorkshire and Humber, East Midlands, West Midlands, South West, South East Central and London (HPA 2007). The outcome of this evaluation was that the dilution of the chemicals rendered the concentrations of the chemical in the flood water low, and the same applied to the possible infections from sewage in floodwater. This dilution process rendered the risks to the general public of this flooding relatively low. The Agency was of the opinion that the general public can markedly decrease the risks of infections by avoiding possible infectious floodwaters. The Agency also concluded that the same assessment is also most likely applicable to the chemical pollution even though the final conclusions still require further considerations.

Europe - flooding in central Europe - Germany, Poland and Czech Republic

The river Elbe is one of the major rivers in Central Europe. It flows over a distance of 1091 km through Czech Republic and Germany. Extreme and widespread precipitation over Austria, Czech Republic, Slovakia and Germany lead to a disastrous flood in 2002. In the flood area there were several chemical factories, among them the Spolana chemicals factory in Czech Republic which handles and treats with particularly problematic chemical substances. Spolana is a chemical factory producing basic chemicals, pharmaceuticals and plastics. High water caused floating of chlorine tanks and loss of their containment. Altogether 80 tons of chlorine was released and most of it was diluted in the flood waters and small amounts in the air.

There were several sewage treatment works in the area. Substances from these sources gave rise to a serious pollution situation the extent of which was considered, however, to be very difficult to assess. Vegetation was damaged by gaseous chlorine, and soil and sediment were contaminated by dioxin and related compounds (Stachel et al. 2003;Stachel et al. 2005) and P. Danihelka (Danihelka 2008). In the Czech Republic there were altogether 139 Seveso classified operators, 70 as 'A' lower tier, and 69 as 'B' upper tier operators during the September 2002 floods.

The study by Stachel et al (Stachel et al. 2003) collected sediment layers from 37 sampling sites along the Elbe and the mouths of tributaries. The aim of the study was to analyze dioxins (PCDD/F), xenoestrogen-like branched nonylphenols (NP), nonylphenol ethoxylates (NPEO) and bisphenol A (BPA), organotin compounds, brominated flame retardants, trisalkylphosphates, DEHP, organochlorine compounds, PAHs, synthetic musk fragrances, radionuclides and metals. Significant concentrations of PCDD/F could be shown in several in the soil of flooded areas (Stachel et al. 2003;Stachel et al. 2005). The concentration of NP dominated, and the origin of these compounds was most likely the discharge of treated waste water from the sewage plant. In agreement with this observation, the NP concentrations were two orders of magnitude lower upstream from the location of the leaks. The concentrations of NPEO and those of BPA were higher in the vicinity of Spolana chemicals, a manufacturer of BPA. Monobutyltin (MBT), dibutyltin (DBT), and tetrabutyltin (TeBT) were elevated in several areas, the TeBT concentration being the most remarkable. The origins for these compounds could be traced to discharges from a manufacturer of antifouling agents and the local shipyards.

In another report concerning the Elbe flood in 2002, the concentrations of various nutrients such as phosphates and nitrates, silicates and most heavy metals were within normal range. Mercury concentrations were elevated in some sampling sites, but were still below the values observed during mid-1990s. For alpha-HCH and beta-HCH up to 10-fold elevated concentrations were observed. Some herbicides like atrazin showed about 5-fold elevated concentrations (Common Wadden Sea Secretariat, Wilhelmshaven, Elbe Flood Status Reports, 2002, http://cwss.www.de/news/news/elbe-flood-2002.html#5) as compared with the normally occurring ones.

The Federal Ministry of Education and Research (BMBF, Germany, http://www.bmbf.de/en/index.php) carried out an Ad-hoc Project concerning the Elbe flood in 2002, and the outcome of the project was reported in 2003 (http://www.halle.ufz.de/hochwasser/index.php?de=1298). In this project, several chemical compounds were determined including elements Cd, Pb, Zn, Cr, Cu,, Ni, As, U, Hg, Ti, Sn, and radioactivity, organic compounds PAK, PCB, chlorobenzole, DDT, HCH, mineral oils, and regional specific compounds, dioxin. The determinations were carried out in several different places in the flooded area.

As a part of this Ad-hoc Project (Anacker et al. 2003) explored concentrations of Pb, Ni, Cd, Hg, Cr, Zn, Cu, and As in the sediments of several places in the flooded area, and a wide variety of the chosen heavy metal and As concentrations were found. In the samples, As and Hg were occasionally present in higher concentrations. Cd, Pb and Ni concentrations were not elevated. As to the measured organic compounds (BaP, β-HCH, PCB, DDT, HCB, Dioxin and MKW), there were increased levels in some of the sediment samples. The concentrations were at similar level with frequently occurring levels in those specimen sites for PCB and

DDT, 2 fold elevated for β-HCH and the same level or even less than usually for the other measured organic compounds (Anacker et al. 2003).

Einsporn et al (Einsporn et al. 2005) explored possible effects of Elbe flood in 2002 to the cellular changes in flounder livers and digestive glands of blue mussels in the Elbe estuary and the Wadden Sea. The relevant concentrations of the contaminants such as organochlorides and PCBs were analyzed in parallel with cellular biomarkers; elevated concentrations of insecticide metabolites were detected. Cell recovery and clear reduction in contaminant concentrations were observed in fish livers five months after the flood at nearly all sampling sites as compared with the concentrations during the episode. (Einsporn et al. 2005)

In Czech Republic the changes of Pb and Cd were studied in the bottom sediments before and after flooding (River Malše, August 2002). The flooded area is also the main source of drinking water in this area. The mobility factors for Pb and Cd were calculated, and the results showed that the flood led to a leaching of the heavy metals present in bottom sediments into the environment (Chrastny et al. 2006).

In Italy, in the Dese River (Venice Lagoon) a flood was generated by a typical summer storm. For the investigation, water samples were collected for the analysis of total and dissolved metals (As, Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb and Zn), nutrients and the suspended particle matter (SPM) concentration. The transport of the most metals were driven by the SPM, as the increase in concentration of SPM had a high correlation with increased levels of Fe, Cu, Pb, Cr, Ni and particularly Zn transported by the stream (Zonta et al. 2005).

Europe - Flooding in Spain

Mobilization of pesticides into surface waters along the Guadiamar river (Spain, 1998) on an agricultural landscape flooded by a torrential storm was studied by Donald et al (Donald et al. 2005). The authors concluded that significant amounts of herbicides were mobilized to aquatic environments when prairie agricultural landscapes were subjected to torrential storms and flooded. Flooded wells and small municipal reservoirs used as sources of drinking water were compromised by 10 or more pesticides and some of them in relatively high concentrations. Carbera et al (Cabrera et al. 1999) analyzed heavy metal concentrations in soil samples of seven selected areas along Guadiamar river valley affected by toxic flood, after removal of a deposited sludge. Elevated concentrations of nine elements (As, Au, Bi, Cd, Cu, Pb, Sb, Tl and Zn) out of the 23 elements analyzed were higher in sludge covered soils than in unaffected soils. The values of total As, Au, Pb, Sb, Tl and Zn in sludge-affected soils were higher than the upper limits for normal soils world wide. (Cabrera et al. 1999)

Europe - Flooding in France

Fresh floodplain deposit (FD) from 11 key stations, covering the Seine mainstream and its major tributaries were sampled from 1994 to 2000 in order to analyze the temporal trends of the metal concentrations (Cd, Cu, Hg, Pb and Zn) subsequently to flooding. Throughout the Seine River basin FD levels were elevated as were those of Cd, Cu, Hg, Pb and Zn by a factor of two or more (Grosbois et al. 2006).

Chemical incidence response - the role of odor

Odor can be generated from many different sources like accidental chemical spills, as well as from incinerators, landfills and mineral refining facilities. During chemical incidents, odors are often reported as 'complaints' (Smethurst 2007a;Smethurst 2007b)), but often the source of

odor is unknown. Odors are often perceived as either a nuisance or as a direct threat to health. The difficulty in explaining the symptoms attributed to odor is a challenge to the health protection response and regulation measures.
Smethurst (Smethurst 2007a)has developed a checklist in order to assist with the investigation of odors hazard identification, exposure assessment and risk characterization, as well as recommendations for the acute phase response, legislative aspects, and recommendations for post incident investigation to manage the risk of odors. The draft checklist presented in Annex 1 (Smethurst 2007a) giving the odor characteristics and the detection threshold levels over 100 chemicals is designed as an aide-mémoire for public health professionals and other emergency responders when dealing with odors.

Public health impacts of chemicals in floods

Euripidou and Murray (Euripidou and Murray 2004) reviewed three floods related to chemical incidents in England i.e. Yorkshire flood (2000), Gloucestershire fire and floods (2000) and Kent floods (October 2001). These floods were chosen, because the chemical contamination had the potential to affect public health either primary from soil or water and secondary from homes or via other contamination. This was verified by demonstrating that one or more chemicals were found in land, homes, flooding sediment or water in concentrations above or soil guideline levels with a potential to cause both acute and chronic adverse health effects.

From October 28 through November 8, 2000 in Yorkshire, severe flooding due to high rainfall caused the risk to clean-up workers to be exposed to dioxins (2,3,7,8-TCDD), because this area was earlier heavily contaminated with elevated levels of dioxins by heavy industry. There was evidence that dioxin residues may become mobilized from rivers, canals, storm water and sewage drains. In Gloucestershire, a fire destroyed approximately 160 tons of hazardous waste containing drams including a wide range of chemicals such as cyanide, resins and adhesives, pesticides, solvents, asbestos and low level radiation waste. In Kent floods in October 2001 vast amounts of oil waste was mobilized by the flood waters, and 140 people were evacuated to rest centers and over thousand people displaced (Euripidou and Murray 2004).

Euripidou and Murray (Euripidou and Murray 2004) listed the following chemicals as causes of possible chemical contamination during flooding in the case that they reported in UK (Table A2).

Table A2: List of chemical contaminants reported after the 2001 flood in Kent, UK (Euripidou and Murray (Euripidou and Murray 2004))

Flooding	Source	Chemical contaminants
Storm water floods	run-off from roads, motorways and bridges	- heavy metals - pesticides, fertilizers and herbicides - hydrocarbons - oils and grease - petrol and fuel depots - spilled petroleum products - paint and rust - sodium and chlorine
Overloaded sewers	sewer pipes - residential, industrial or storm water - run off - remobilization	- variety of residential, industrial and storm waste water - domestic and industrial sources
Hazardous landfill sites	physical contamination	- hydrogen sulphide and mercaptan

Wastewater lagoon	contamination of soil, sediment or groundwater	- persistent chemicals - asbestos - mercury - VOCs - PAHs - dioxins - persistent chemicals, e.g. wood preservatives
Acid mine drainage	coal mines	- sulphides - oxidation to sulphuric acid - aluminum, arsenic, cadmium, cobalt, copper, iron, lead, manganese, nickel, silver and zinc

Guidance for handling chemicals in floods
All the chemicals despite the use should be stored in a proper way following the regulatory and other guidance given by the national authorities. International bodies, like United Nations different organizations ILO (International Labour Organization), WHO (World Health organization) and CIEN (The Chemical Information Exchange Network) as well as OECD and European Union legislation, recommendations and guidance provide huge amount of information for the safe management of chemicals.

Several institutes and authorities in Europe and USA have published guidance how to prepare for floods and what to do during and after floods.

- Health and Protection Agency, Flooding, United Kingdom
  - http://www.hpa.org.uk/flooding/default.htm
- NIEHS web pages
  - (http://tools.niehs.nih.gov/wetp/index.cfm?id=391)
- CDC - Floods and returning home
  - http://www.bt.cdc.gov/disasters/floods/pdf/after.pdf
- US EPA, Flood Cleanup and the Air In Your Home
  - http://www.epa.gov/mold/flood/flood_booklet_en.pdf
- US Department of Labor, Occupational Safety & Health Administration
  - http://www.osha.gov/OshDoc/floodCleanup.html
- University of Wisconsin Madison Extension 'Pesticide Storage Concerns During a Flood'
  - http://www.cdc.gov/nasd/docs/d001401-d001500/d001488/d001488.pdf
- Health and Safety Universal Precautions for Post-Flood Buildings
  - http://siri.uvm.edu/library/flood.html
- *Conserve O Grams*
  - http://www.nps.gov/history/museum/publications/conserveogram/cons_toc.html)
  - Health and Safety Hazards Arising from Floods http://www.nps.gov/history/museum/publications/conserveogram/21-01.pdf

The following guidance is collected from several sources (see above):

Preparing for floods
In order to be aware and prepare for possible flooding and prevent the area from accidental chemical spills, special attention should be paid to the types of chemicals used, stored and transported in the area. These chemicals might be industrial or commercial chemicals, pesticides, disinfection chemicals, paints, lacquers, diesel, gasoline, oils, chlorine, and metals,

PAHs, PCBs, dioxins, liquid oxygen, waste, medical waste and corrosives. The source for chemicals contaminating the floodwater might be also from the remobilization from the soil.

In case of flooding the chemicals inventory in different sites could provide the information which chemicals might get in contact with flooding water. This information is for importance to the rescue and cleaning groups and the inventory can be done in different sites:

- Industry sites, uses, stores, transportation and processes
- Agricultural use, stores, transportation and use
- SME's use, stores and transportation
- Gasoline stations (underground fuel tanks) and oils
- Laundries and dry cleaning using and storing chemicals
- Hazardous waste sites

When making the preventing plan

- Purchase chemicals only for a single season (e.g. pesticides) or a reasonable short period.
- Store chemicals preferably above the (frequent) flood level or above the ground when possible.
- Develop an emergency response plan.

During and after flooding

Cleanup procedures after the flooding might vary very much depending on the area and which facilities are available e.g. fire brigades with proper instructions and protective measures.

Chemical contamination

- Use extreme caution in the area of flood and be aware of potential chemical hazards. Flood waters may have may have buried or moved hazardous chemical containers or other industrial chemicals from their normal storage places.
- There might be danger out of all gas lines and oil tanks, if not broken, but leaking.
- There might be danger of fires and explosions (e.g. tanks from gas grill or household propane tanks).
- Car batteries can cause electrical danger and danger of acid spills.
- Portable generators, grills, camp stoves or other gasoline, propane or natural gas devices should not be used indoors for heating or boiling water because this might lead to carbon monoxide poisoning.
- Consider all unusual odors or irritation of the skin and mucous membranes as to be signs of toxic chemical exposure, unless proved otherwise. Note also, that chemicals don't have odors that warn of their presence.
- Gardening chemicals and other household chemicals used in garages and cellars might cause harm.
- Protective measures should be used until the hazard is proven to not exist.
- Consider all pooled water inside and outside the buildings to be biological or chemical exposure hazard, unless proven otherwise by qualified personnel.
- Combustion of different equipment destroyed by the flood can also cause chemical contamination.
- Be aware of the possible hazard of the building materials which have been devastated during flooding.
- Children should not be allowed to play in flood waters or with toys that have been in contact with flood waters.

Cleanup and decontamination recommendations

Assume that any water in flooded or surrounding areas is not safe unless the local or state authorities have specially declared it to be safe.

- Crucial information is which chemicals were involved in flooding (oils, chlorine, pesticides, disinfection, very reactive chemicals, possibility of carbon monoxide poisoning, etc.).
- All the chemicals should be moved as soon as possible out from the water.
- All the damaged chemicals including the household chemical should be destroyed in the best possible way.
- Cleanup workers may need to use special chemical protective outer clothing and goggles, plastic or rubber gloves, safety boots and other protective clothing and respirators to avoid skin contact and inhalation of vapors.
- Maintain good hygiene during cleanup operations.
- Surfaces need to be cleaned and decontaminated.
- Do not mix detergents with chlorine-based bleaches as this may release hazardous fumes.

Typical possible symptoms

- Eye, nose, throat, upper respiratory tract, and skin irritation.
- Flu like symptoms.
- Central nervous system depression, fatigue, loss of coordination, memory difficulties, sleeplessness, mental confusion.
- Chronic effects depend on the extent and the duration of exposure.
- Headache, nausea, diarrhea, sweating, breathing difficulty and tremors or convulsions (especially in relation to pesticide poisoning).
- Shortness of breath, chest pains, swelling of abdomen (asbestos exposure).
- Fatigue, depression, heart failure, abdominal pain, anemia, kidney failure (lead poisoning).
- Dizziness, chronic headaches or nausea, excessive tiredness, cherry red skin color (carbon monoxide poisoning which can lead to sickness or death).
- Medical first aid treatment and medical advice should be present.
- Anyone who develops unusual symptoms should seek immediate medical attention.

Conclusions and best practices

To prevent human diseases due to chemical hazards during and after floods, the knowledge of which chemicals are possibly present in the flooded area is of utmost importance. Inventories made beforehand facilitate the rescue plan and ensure that clean up operations are done safely and properly. When chemicals are stored in a possible flooding area, and especially in the frequent flooding areas, 'normal' chemical levels can be taken into account. When planning chemical storage, the turn-over rate should be set so that chemicals are stored in smallest possible amount for short periods. Guidelines regarding chemicals in floods can be prepared for the most common chemicals and adapted to the area. Guidance to use personal protective equipment (boots, gloves, goggles, protective clothing, and respiratory protection) can also be prepared taking into account the circumstances in the country and area.

General and detailed information concerning the safe use of chemicals can be provided to citizens on a routine basis. The better people understand the dangers and safe use if the chemicals which they use and store e.g. in their homes, the better the possibilities to manage the situation in case of floods.

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