# PART I: Literature Review
# Health Impact of Natural Disasters
# (Earthquakes, windstorms and floods)

**MICRODIS Health Working Group - 2008**

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## List of abbreviations

| | |
|---|---|
| ARI | Acute Respiratory Illness |
| 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 |
| SVOCs | Semi Volatile Organic Compounds |
| VOCs | Volatile Organic Compounds |
| TB | Tuberculosis |
| WHO | World Health Organization |

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## 1 Introduction

Disasters results from the impact of extreme events, i.e. intense physical phenomena, on human life and human environment. A disaster is described as "A 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) Center for Research on Epidemiology of Disasters (CRED) defines disasters as a situation or event, which overwhelms local capacity, necessitating a request for national or international external assistance (WHO. 2007)

This document focuses on the health impact of natural disasters and among those on earthquake, windstorms and floods.

### 1.1 Disaster classification

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

**Table 1: Classification of disasters (CRED 2008a)**

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

Disasters differentiate themselves according to their predictability, initial lethality, scope of geographical impact, and onset delay time. Table 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 because 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" (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.

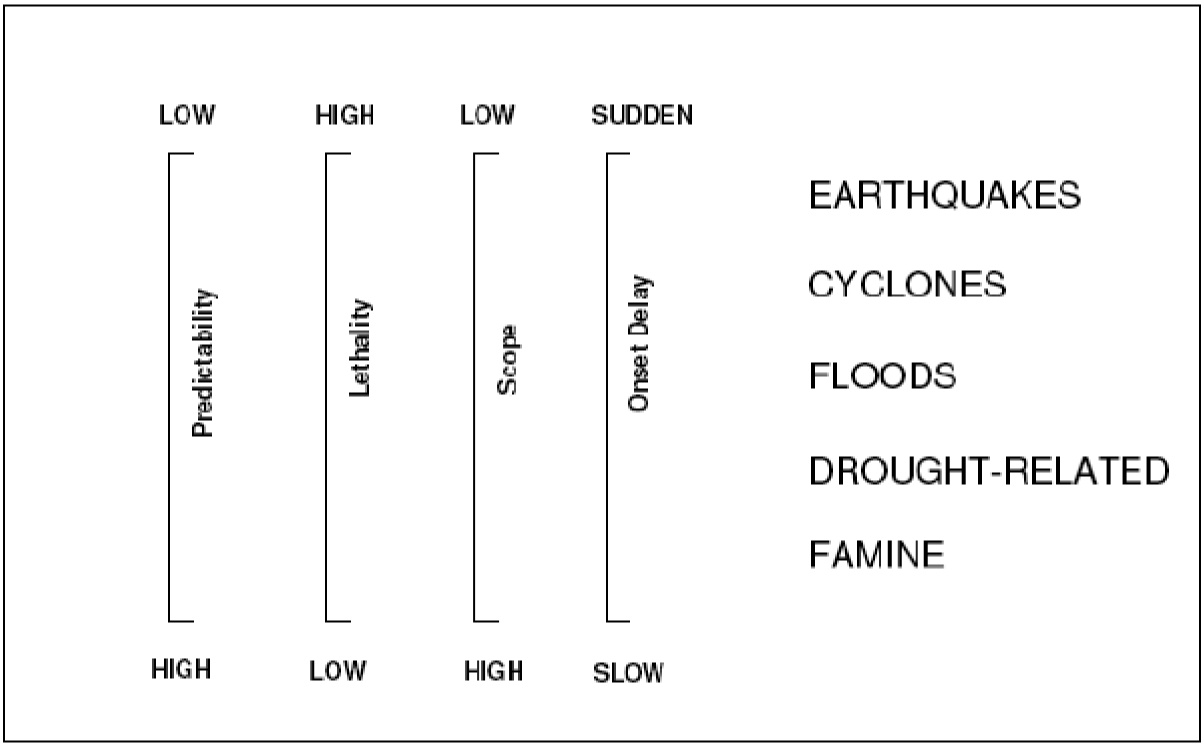


**Figure 1: Disaster characteristics assessment scale (Guha-Sapir 1986;Guha-Sapir and Lechat 1986b)**

**1.2 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 poor 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).

Earthquakes were responsible for almost 27% of all deaths from natural disasters (highest proportion from any disaster type) over the last 30 years (CRED 2007). Asian countries are more prone to earthquakes as it is a seismically active region. Amongst these again, the human impact of the earthquakes has been enormous. It ranked 4th amongst the most affected countries in 2006 (Indonesia ranks first) (CRED 2007). Table 2 summarizes the frequency and the number of deaths and injured in specific country of interest to MICRODIS (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)**

| | Earthquake | | | Windstorm | | | Flood | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | Deaths | Injured | N | Deaths | Injured | N | Deaths | Injured |
| **Asia** | | | | | | | | | |
| India | 3 | 21316 | 173434 | 23 | 679 | 5204 | 82 | 10536 | 400 |
| Indonesia | 29 | 7070 | 147079 | 2 | 4 | 0 | 43 | 2563 | 1283 |
| Philippines | 1 | 15 | 100 | 57 | 5158 | 4959 | 23 | 286 | 67 |
| Vietnam | 0 | 0 | 0 | 25 | 761 | 2349 | 29 | 1790 | 463 |
| **Europe** | | | | | | | | | |
| Belgium | 0 | 0 | 0 | 2 | 7 | 2 | 6 | 2 | 0 |
| France | 0 | 0 | 0 | 13 | 52 | 202 | 18 | 44 | 13 |
| Germany | 1 | 0 | 0 | 13 | 75 | 451 | 6 | 36 | 128 |
| Italy | 4 | 30 | 44 | 2 | 1 | 0 | 12 | 75 | 22 |
| UK | 0 | 0 | 0 | 7 | 53 | 4 | 12 | 15 | 8 |

**1.3 Hazards, vulnerabilities, risks in relation to overall impact**

The effects of disasters on populations differ in intensities and change from one disaster to the other (PAHO 2000) and the numbers of impact death (caused immediately as a result of the disaster) vary greatly from one disaster to the other (CRED 2008b).

A range of factors shape the overall outcome of disaster impact. The disaster per se is the hazard and is defined as "A possible threat of source of exposure to injury, harm or loss, e.g. conflict, natural phenomena (Inter-Agency Contingency Planning Guidelines for Humanitarian Assistance 2001)". Vulnerability has several dimensions. WHO defines vulnerability as "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 all fields of disaster management. Poverty is also one of the main causes of vulnerability in most parts of the world" (WHO. 2007).

Vulnerability could be individual or as per a group (population 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. 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.

### 1.4 Generalized health impacts, pathways, and causality assessments

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.

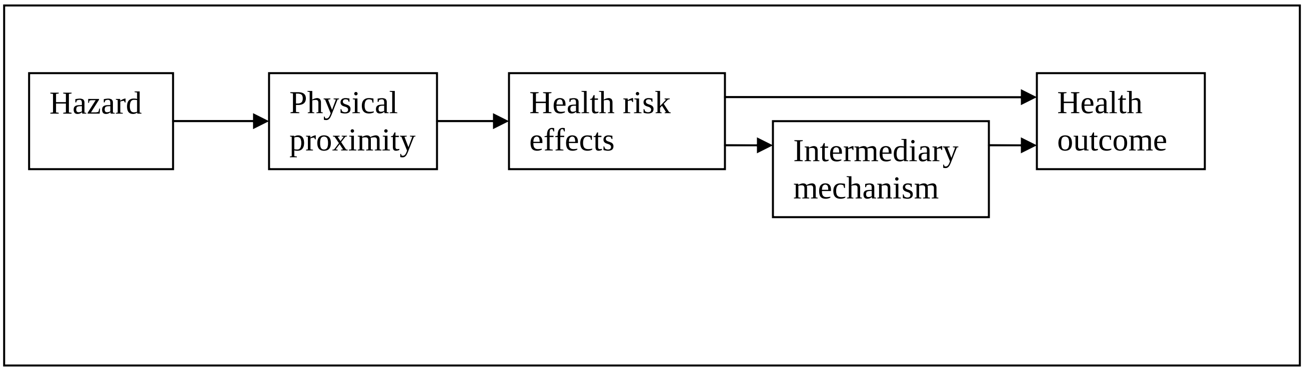


**Figure 2: Generalized health impact pathway for climatic hazards (Few 2007)**

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.

Figure 3 summarizes in general the health and health systems impacts of natural disasters. Health impacts include mortality (death) and morbidity in term of injuries, increased transmission of communicable diseases, inadequate treatment 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.

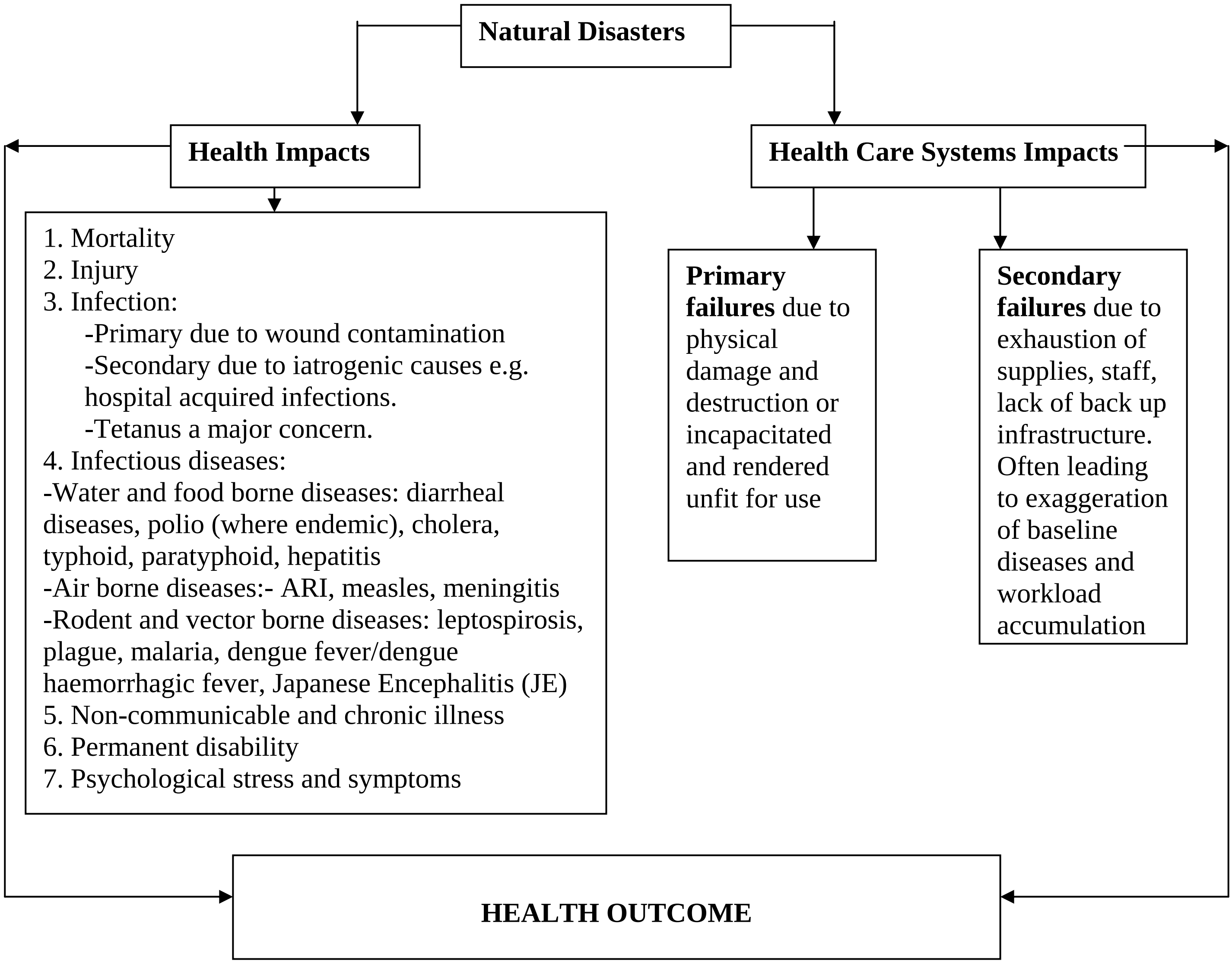


**Figure 3: General health and health systems impacts of natural disasters**

## 2. Methods

The literature review is based on the search in "Pubmed" and "Web of Science" databases. While both cover a extensive number of publications, Pubmed specialized on medical topics while Web of science covers more technical aspects and applied sciences. Key words used are summarized in Table 3 and shows the number of outcome papers in the each database.

**Table 3. Keywords used in literature search in Pubmed and web of science database**

| Key words | And | Pubmed | Web of science |
|---|---|---|---|
| Natural Disaster | Health | 192 | 296 |
| | | | |
| Windstorm* | Health | 1 | 0 |
| Windstorm* | Disease* | 1 | 8 |
| Storm* | Health | 847 | 485 |
| Storm* | Disease* | 1094 | 498 |

| | | | |
|---|---|---|---|
| Flood | Health | 816 | 493 |
| Flood | Disease* | 835 | 507 |
| Earthquake | health | 2065 | - |
| Earthquake | Disease* | 720 | - |
| Earthquake | trauma | 717 | - |
| Earthquake | injury | 599 | - |
| | | | |
| Disaster | Health system | 145 | 15 |
| Disaster | Health care system | 96 | 25 |
| | | | |

* stands for any alpha-numeric character

Articles dealing exclusively with mental health were excluded using key word exclusion. Articles were screened on the basis of titles. Relevant articles were sought out and retrieved. When full paper was not available either electronically or as paper copy, only the abstract was considered.

The psychological impacts of disasters were reviewed by Komproe and Wind and are not included in this document.

## 3. Earthquakes

### 3.1 Introduction

CRED reports that from 1996-2005, an estimated 281 earthquakes occurred in 58 countries causing death of more than 162,986 people, affecting 39 million with economic damages of US$ 94 billion (CRED 2008b). The immediate effects of earthquakes include infrastructure destruction and loss or disruption of health care services both curative and preventive. The human impact of earthquakes includes mainly mortality and injury. Earthquakes cause a considerably high number of primary deaths also called as impact deaths. The injury to mortality ratio of most earthquakes has been observed to be about 3 injured to 1 death. This makes the injuries from earthquakes a special concern.

### 3.2 Mortality

Earthquakes cause high impact deaths. These are primarily attributed to the serious injuries sustained and difficulties of rescue or immediate relief. 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.

### 3.3 Injury and infection

Falling debris and entrapment pose the greatest risks for injuries (morbidity). 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 earthquake 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 them 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. This may be viewed as a bias. 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. Second most important is that this was the injury distribution amongst the survivors. One study that did not complete the autopsies on all deceased but observed that commonest injuries seen in those dead was 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).

**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. 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 was 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 injury and crush syndrome both are more common in children 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.

The other 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).

**Reported injuries**

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.

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.

The 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.

**Table 5: Data variables mentioned in the studies reviewed to support injuries observed (Phalkey 2007)**

| Variable | Number of studies reporting | Variable as most frequent injury | Range amongst those enrolled |
|---|---|---|---|
| Psychological Trauma | 7 | | 0-32% |
| Orthopedic injuries | 8 | 2 (both in Gujarat) | 15-45% |
| General Surgery | 2 | | 6-13% |
| Medicine | 6 | 1 | 30-79% |
| Gynecology | 5 | | 5-22 |
| Pediatric Cases | 2 | 1 | 23-37% |
| 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% |
| Extremity Injuries | 9 | 6 | 19-55% |
| Upper Extremity | 10 | Humerus | 10-30% |
| 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% |
| Infections | 6 | | 5-47% |
| Soft Tissue Injuries | 16 | 6 | 10-83% |
| Peripheral Nerve Injuries | 6 | | 1-9% |
| Deaths | 8 | | 2-23% |
| Amputations | 7 | | 1-20% |
| Transfers | 5 | | 0-25% |
| Others | 9 | | 3-77% |
| Unknown | 1 | | 10% |

**Infection**

The falling debris and construction material also pose risks for wound contamination. A large part of victims present with contaminated and often superadded infection in wounds (primary infection). Concern with tetanus particularly in developing countries has not been documented adequately to arrive at useful conclusions (Waring and Brown 2005).

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 the normal baseline hospital settings. However, just one study reported hospital acquired infections for etiology but not overall incidence (Öncul et al. 2002).

### 3.4 Infectious diseases

### 3.5 Chronic illness and disability

Amputations and spinal paraplegia constitute the main conditions contributing for permanent disability. 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. Disability as a patient outcome is not adequately addressed in the literature and this is a significant concern. Most developing countries lack supporting infrastructure for the disabled. The increased economic and social burden on the population resources can be significantly influenced by timely interventions and prevention.

### 3.6 Vulnerable groups

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). Amongst the factors mentioned above, the environmental factors are of special concern. 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. Structural damage is more closely associated with mortality than with morbidity (injury) (Mahue-Giangreco et al. 2001). 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). Table 4 summarizes human, geological and environmental factors playing a role in the health impact outcome after earthquakes.

**Table 4: Factors affecting mortality and types of morbidity after earthquakes (Blaikie et al. 1994;Guha-Sapir 2000;Lechat 1979;Sanchez-Carriallo 1989)**

| **Human Factors** | **Geologic factors** | **Environmental factors** |
|---|---|---|
| Awareness of danger | Time of strike | Population density and distribution |
| Degree of preparedness | Intensity of seismic activity | Building factors: age of the structure, height of the structure, escape routes, occupancy, maintenance |
| Health status:<br>Pre existing morbidity<br>Immediate health status | Magnitude of the earthquake | Structural quality and design including building material and method, |
| Age, Sex | Opportunity of warning | Level of Adherence to seismic codes |
| Location at the time of earthquake (indoor/ outdoor) | Distance from epicenter | Use of structure residential/ commercial, sports complex, parking, industrial |
| Activity engaged in at the time of strike, state of alertness, movement | Ground acceleration, soil type | |

### 3.7 Impact on health care system

The destruction of health care facilities after an earthquake makes the early management of injuries difficult. The patient load accumulates and most structures may be unsafe for use in view of the aftershocks. Although the increase in demand for emergency orthopedic trauma management is initially overwhelming, it is short lived and only transient. Most hospitals report return to baseline function between 4-10 days post earthquake.

Primary failures of hospitals due to structural damage and invariably the death and injury of staff inside the hospital are a serious problem. The most vulnerable population in the society is housed in the hospitals twenty four hours. The evacuation of these is a daunting task. 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.

Baseline medical emergencies are encountered throughout the post disaster phase even on day 0. 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. Increased incidence of stress related diseases like the peptic ulcers and ischemic heart diseases have also been recorded. 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.

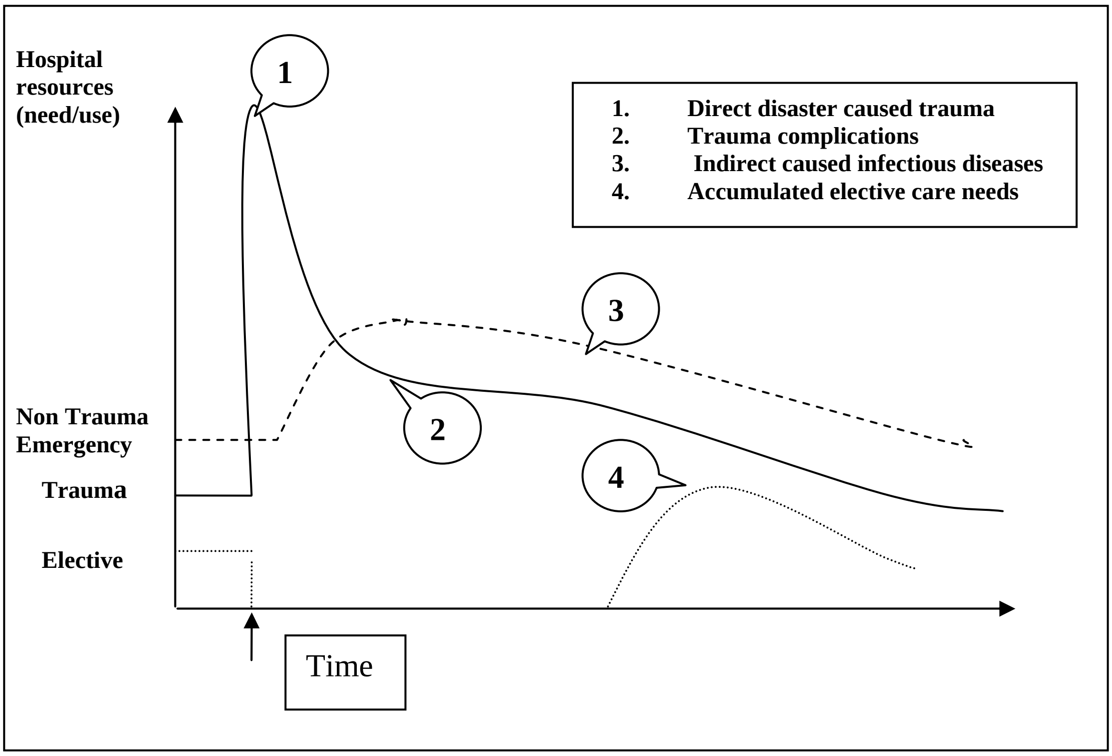


**Figure 4: Conceptual variation of needs/ use of hospital resources before and after a disaster. Modified version adapted from (Riddez 2007)**

## 4. Windstorms

### 4.1 Introduction

Windstorms are classified according to their intensity (i.e. the top sustained wind speed measured) and are referred to as cyclones, typhoons, hurricanes, tropical depressions or depressions, depending of their strength and geographical location. (see "windstorm" glossary). Windstorm can cause storm surge (displacement of see water unto land) or floods due to accompanying heavy rains. The health impacts of flooding caused by windstorms are detailed in section 5 dealing with "floods".

**Destruction of infrastructure**

Damage road and 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 (which are detailed in section 5).

### 4.2 Mortality

Mortality related to windstorm occurs due to the direct impact of the storm but also in its direct aftermath when people return to their home and engage in the reconstruction operations. Other cause of mortality may arise from physical stress related to the occurrence of the storm or evacuation that may precipitate the fatal outcome of a pre-existing medical condition (e.g. heart condition) (Shultz et al. 2005).

**Direct impact**
Deaths caused directly by windstorm results mainly from collapsing structures, falling objects, trees and tree branches falling and causing train or traffic accidents. Storm surges or flash floods that often accompany windstorms can cause drowning. Land slides due to heavy rains are common and may cause high level of casualties.

Developing countries suffer disproportionally from storm mortality and have suffered high death tolls in the last decades while casualties have dropped dramatically in industrialized countries (Shultz et al. 2005).

**Post-disaster**
Because storm forecasting has greatly improved over the past years and has allowed effective evacuation of population away from direct impact zones, the number of direct deaths has decreased (e.g. storm surge drowning) (Bourque et al. 2006) and most casualties occur now in the post-disaster phase upon returning to devastated areas.
During the recovery phase, returning to weakened and unsafe buildings and engaging in clean up operation without proper equipment or safety precautions can present life-threatening situations. For example, residents should be warned against fallen electrical wires to avoid electrocution.

Deaths due to carbon monoxide poisoning are a common feature of disaster aftermath when power supply is disrupted and residents use electricity generators without ensuring proper ventilation of the device (Cukor and Restuccia 2007).

### 4.3 Injury and infection

Due to the violent nature of this disaster, physical injuries are common during windstorm due to 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 sand 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.

### 4.4 Infectious diseases

Destruction of infrastructure and break down of proper sanitation and drinking water systems can lead to an increased number of infections transmitted through the fecal-oral route, such as diarrheal diseases, cholera, typhoid fever and paratyphoid.

In developed country outbreak are rare but sporadic cases can occur. For example two case of toxigenic *Vibrio cholerae* O1 infection were reported in Louisiana after hurricanes Katrina and Rita (CDC 2006b); they affected patient 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 2006a).

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. 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 the storm. Increase number of larva habitats and break down of vector control measures are typical causes responsible for the increase.
For example after hurricane Mitch that hit Central America in October 1998, cholera, leptospirosis, dengue and malaria showed moderate to high increase in at least two of the six countries affected (Honduras, Nicaragua, Guatemala, El Salvador, Costa Rica and Belize) compared to pre-hurricane levels (PAHO 1998).

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).

### 4.5 Chronic illness and disability

Pre-disaster chronic illnesses may be worsened by post disaster conditions, especially medical conditions that need a regular follow-up and a daily treatment. Disasters may have an impact on these chronic diseases not only by the disruption of the living conditions (lack of safe water and food, temperature extremes, etc) but also by breaking down health care services and access to medication. Elderly people seem to be particularly at risk (Mokdad et al. 2005). Another group with special needs are pregnant women and infants, who have unique needs and whose exposure to contaminants may have more serious consequences than for the rest of the population (Hamilton and Halvorson 2007). People with disability also require special attention, notably during the evacuation phase.

Five of the top six major health problems encountered in the aftermath of Hurricane Katrina were chronic health problems (CDC 2005). An estimated 68% of the medications delivered by pharmacies serving evacuees were for chronic health conditions (Jhung et al. 2007), among which antihypertensive drugs were the most commonly dispensed drugs.

However, many people did not get access to adequate medication and, with the complete disruption of regional health infrastructure, treatment of chronic diseases emerged as a critical problem after Hurricane Katrina (Ford et al. 2006). After Katrina, special concern was expressed on the urgency of treating patients with diabetes, cardiovascular diseases and kidney diseases (Ford et al. 2006). 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 problems related with difficult access to medication, other living conditions related to natural disasters may 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), etc…

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).

### 4.6 Vulnerable groups

**Population displacement**

Evacuation and sojourn away from home create stress. As mentioned above, special-need individuals, whose pre-existing medical 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 the process.

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.

### 4.7 Impact of health care system

Health care facilities can be directly affected by storms and not be functional after the disaster. In addition staff member themselves affected may not be available to work even if temporary facilities are set up. Such conditions represent a burden that can affect emergency care, drug procurement and control programs and overall make the public health response more difficult.

## 5. Floods

### 5.1 Introduction

The causes of flooding vary depending of circumstances and geographical settings. In coastal areas flooding can be caused by tidal surge following a windstorm that brings see water unto land. River floods are caused by overflowing rivers onto plane areas. Heavy rainfalls can create 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. The onset of flood can occur at different speed and one can distinguished slow-onset flooding occurring over days or weeks and typical of river floods; rapid-onset flooding occurring over hours or days typically from rivers that may have received heavy rainfalls upstream; and flash-flood occurring within minutes or hours following heavy rainfall or structure collapse.

Not all floods are disasters. In many place floods are regular features of nearly yearly occurrence. They also bring positive aspects such as fertilization of the fields and as such are

seen a natural event, which they are. Floods become disasters when they are of unusual proportion or occur in usual place or unexpectedly.
In 2006, there was a statistically significant increase in the number of floods reported. Of the 235 natural disasters reported more than half were floods (CRED 2007).

**5.2 Mortality**
Fast moving waters from storm surge or flash flood cause death by drowning or trauma as people are hit by floating objects (Ahern et al. 2005). People trapped in vehicles caught in moving waters is also a frequent cause of mortality.

**5.3 Injury and infection**
Injury and trauma are common when people are hit by floating object or have to wade into flooding waters. Contact with contaminated environmental waters can cause wound infections.

Secondary infections occur when injuries are not treated properly and hygiene is poor. Tetanus is a major concern in population where immunization levels are low.

**5.4 Infectious diseases**
Flooding can increase the risk of soft tissue, respiratory, diarrheal and vector-borne infectious diseases as a result of the direct inoculation of pathogenic organisms (tetanus, wound infections, aspiration pneumonia), the destruction of shelters and resultant crowding of surviving displaced individuals (influenza, measles, meningitis, tuberculosis), the elimination of potable water supplies (shigella, cholera), and altered vector breeding grounds or zoonotic reservoirs (malaria, dengue, abroviral encephalitis. Flooding can also have long term and secondary effects, such as disruption of vaccine, maternal - child health, and tuberculosis public health programs (Ahern et al. 2005;Ivers and Ryan 2006).

**Water- and food-borne diseases**
Because water pools are mixed after heavy rains and during floods, fecal material can find there way easily into water bodies from which water is taken for drinking or for food preparation Therefore this opens the door to increased frequency of transmission through fecal-oral route. Cholera and typhoid fever and diarrheal diseases can thus be on the rise after such events.

**Diarrheal diseases**
Diarrheal diseases that can break out after a flood include cholera and caused 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.

**Air-borne diseases**
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.

Moulds 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.

**Vector-borne diseases**
Vector-borne diseases incidence can increase after a flooding event because of two mechanisms. The first is that the increased number of breeding sites increased with more water availability. Such trends are typically observed during the rainy season. The second is that the disaster can disrupt established vector-control measures and lead to an increase of disease cases after a while.

***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 (Ivers and Ryan 2006). 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 (Krcmery et al. 9999).

***Dengue fever and dengue hemorrhagic fever (DHF)***
The risk of dengue fever and dengue hemorrhagic fevers was reportedly higher after floods (Vasconcelos, 2006).

The risk increases also for other vector-borne diseases such as West Nile virus, Japanese Encephalitis, yellow fever, filariasis, and schistosomiasis.

**Rodent-borne diseases**
Outbreaks of leptospirosis are typical of post-flood periods particularly in urban slum areas. Urine from rodent carries the pathogen that comes in contact with human through flood water. This for example has occurred in Jakarta and in Brazil in the past few years.
Plague can also pose a problem as was the case in India in recent years when rodent populations are displaced get in contact with humans

### 5.5 Chronic illness and disability
People with chronic illnesses and disability can particularly suffer is they are unable to evacuate or reach safe ground. When the flood is of great amplitude and drug supplies are not available, this can lead to treatment interruption for chronically ill patients

### 5.6 Vulnerable groups
Chronically ill patients and the disable suffer a greater burden after the disaster. People with special need such as the elderly, pregnant women and infants can be exposed to conditions that are potentially damaging. Groups that are socially less secure such as the poor, women and migrant are at greater risk to fare less well when dealing with the event.

### 5.7 Impact on heath care system
As in every disaster health care systems can be affected by destruction of infrastructure of its services reduced due to lack of personal or insufficiencies in supplies.

### 5.8 Chemical contamination (by Luotamo and Savolainen)

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

(References listed at the end of this section- to be incorporated in final list).

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, 2002 298 /id} 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, 2006 289 /id}

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, 2001 285 /id}. 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, 2001 285 /id} 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, 2001 285 /id}.

***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 (Headley et al. 2002) 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. 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, 2003 303 /id;Stachel, 2005 304 /id} and P. Danihelka, (http://www.srv.se/upload/F%C3%B6rebyggande/NCO/Arrangemang/Workshop/Presentations/IV-Dobes.pdf) (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, 2003 303 /id} 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, 2003 303 /id;Stachel, 2005 304 /id}. 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 6: 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<br>- pesticides, fertilizers and herbicides<br>- hydrocarbons<br>- oils and grease<br>- petrol and fuel depots<br>- spilled petroleum products<br>- paint and rust<br>- sodium and chlorine |
| Overloaded sewers | sewer pipes - residential, industrial or storm water<br>- run off - remobilization | - variety of residential, industrial and storm waste water<br>- domestic and industrial sources |
| Hazardous landfill sites | physical contamination | - hydrogen sulphide and mercaptan<br>- persistent chemicals<br>- asbestos<br>- mercury |

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

**Guidance for handling chemical 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 Organisation), WHO (World Health organisation) 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, 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.

## 6. Summary of findings

This section gives an analytical summary of the findings. It is organized not by disaster type but by feature topics common to all disasters. A specific perspective for the MICRODIS project is given at the end.

### 6.1 Mortality and morbidity

Death (fatal injuries, drowning) and injuries that may lead to long term disability are directly linked to the disaster. However, a significant part of the mortality and morbidity burden may take place in the post-disaster phase.

**Destruction of infrastructure**

A common feature of many disasters is the subsequent destruction of infrastructure such as transport links (roads, bridge, 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.

### 6.2 Injury and infection

### 6.3 Infectious diseases

Infectious disease outbreaks are unlikely in developed countries although sporadic cases are possible. 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.

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.

### 6.4 Chronic illness and disability

Exacerbation of chronic medical conditions during or after disaster may contribute substantially to the public health burden of disasters. Appropriate drug procurement and handling of chronically ill patients is a crucial point of the post-disaster response effort. These aspects have not been well studied.

### 6.5 Chemical contamination

Chemical contamination can pose immediate or long-term health problem. Although often neglected, especially in less developed countries, it is a serious problem from both a human health and an environmental point of view.

### 6.6 Mental health

Mental health problems characterized by post traumatic stress disorder (PTSD), depression and anxiety are to be found after of all type of disasters. It is a very important aspect

### 6.7 Vulnerable groups

People with specific health needs such as the pregnant women and infants, the elderly, chronic patients, the disable and people who are socially less secure such as the poor, migrants, and depending of the context, women and children are at higher risk of negative health outcome after a disaster. Therefore special effort should be made consider their special risks and needs.

For example, reaching out to migrant minorities, who are often marginalized or making announcement in various languages or through media that serve these communities, can help effective public health measures.

### 6.8 Impact on health care systems

Loss of facilities, loss of personal

Maintaining functioning health care systems after a disaster may be a challenge. As illustrated above, drug procurement may be a problem. Global health initiatives and national control programs may not be able to operate. Immunization programs

In the direct aftermath of a disaster outside help may be able to fill the gap and provide immediate care. However middle- and long-term service may still be in jeopardy.

### 6.9 Guideline for effective response

The quality of response affects the health outcome. The following points are important in minimizing the health impacts after disasters:

- Informing the public on public health issues (communication network): e.g. water quality
- Supplying safe water
- Assuring cooperation and coordination between emergency service agencies and local government
- Establishing surveillance, which is essential to detect new cases of disease earlier on and prevent outbreaks. Surveillance is also important to recognize specific and possibly unexpected needs of public health relevance at the local level in post disaster situations.
- Evacuating and dealing with displaced people.

### 6.10 Evidence overview

Table 7 gives an overview of the disaster impact. 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 7: Health impacts after disasters** (modified from (del Ninno et al. 2001;Few 2007))

| Health Impact | Floods/Windstorms | Earthquakes |
|---|---|---|
| Health Risks | 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 |
| 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 |
| Oral-fecal and water borne diseases | Contamination<br>Disruption of water and sanitation systems<br>Non-specific Diarrhea, skin lesions | Source contamination less likely.<br>Possible systemic disruption |
| Vector/Rodent Borne Diseases | Altered breeding conditions<br>Malaria, dengue, leptospirosis, plague | Rodent borne disease a possibility, no significant effect on vector breeding |
| Respiratory Diseases | Dampness and mould in houses<br>Pneumonia, fever | Exposure to cold weather due to loss of shelter especially children<br>Flu and Pneumonia, Exaggerated COPD |
| 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 |
| Gender Issues | No special vulnerabilities identified other than baseline , consequences in children more serious | No statistically significant special vulnerabilities |

### 6.11 Knowledge gap

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.

Mental health issues represent an important health impact of all disaster. There is a lot of literature linking disasters and mental health outcome.

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, personal, is not well studied.

**6.12 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

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 over an area, service, capacity, recovery, emergency planning, disease surveillance

## Glossary

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

**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".

**Floods (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 2008c).

**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 2008c) : 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 storms (maximum wind speed up to 33 knots = 60 km/h), tropical depressions (maximum wind speed between 34 and 63 knots = 62-115 km/h), or cyclone/hurricane/typhoon (maximum wind speed greater than 64 knots =116 km/h) according to their location in Indian Ocean and South Pacific region/ the Atlantic, Caribbean , Gulf of Mexico, the eastern North and central Pacific Ocean/ or the Western North Pacific and South China Sea, respectively.
-Tornado (CRED 2008c): 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.

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