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FLOODS AND PUBLIC HEALTH CONSEQUENCES, PREVENTION AND CONTROL MEASURES

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This paper is a review of the health consequences of floods. There is little literature on the health consequences of floods in Europe, most of available scientific evidence comes form investigations in the United States, United Kingdom, China and Bangladesh. Although similar effects might be expected to occur in other parts of the World and in Europe, caution must be exercised in transposing those findings from one setting to another. Within Europe there are important differences regarding flood prevention measures, and the use of areas subject to floods and of the territory. These differences may also have an effect on the severity of health outcomes, resulting from flood events. Preventive and control measures are addressed in order to be a useful tool for the UNECE task force on flood prevention and protection with Germany as lead country and the code of practice the task force is developing.

Introduction

Storms and floods are the most common natural disasters worldwide, in terms of economic and insured losses they are the most costly. In the 1990s several floods affected the European region. Table 1 reports some examples, according to the number of deaths and estimated economic damage.

Table 1: Examples of floods in the 1990s in Europe

Flood events (river/year)	**Acute fatalities**	**Damage (estimates)**	**Remarks**
Tazlau (Romania)	107	0.05 billion ECU	Breakdown of the Tazlau dam
Ouveze 1992 (France)	Nearly 100		Campsite
Rhine/Meuse 1993/94	10	1.1 billion ECU	
Po 1994	63	10 billion ECU	Catchment area covered by up to 60 cm of mud
Rhine 1994/1995	None	1.6 billion ECU	Evacuation of 240 000 inhabitants in the Netherlands
Glomma and Trysil River Basins (Norway) 1995	None	0.3 billion ECU	
Pyrenean river 1996	85		Campsite
Oder, Labe, Vistula and Morava 1997	105	5.9 billion ECU	195 000 people evacuated, great material losses
Lena (Republic of Sakha, Yakutia, Russia), 1998	15	1.300 million roubles	51.295 people evacuated, complete interruption of transport system, great material loss

Adapted from EEA, 1998

With the exception of some floods generated by dam failure or landslides, floods are climatological phenomena which are influenced by the geology, geomorphology, relief, soil, and vegetation conditions (Ward, 1978). Floods may also be intensified by human alteration of the environment such as alterations in the drainage patterns from urbanisation, agricultural practices and deforestation. Meteorological and hydrological processes can be fast or slow and can produce flash floods or more predictable slow-developing floods, also called riverine floods.

Flash floods, have two characteristics: They follow a causative event- such as excessive rainfall in a catchment system or the sudden release of large volumes water, with great velocity, in a natural or human made dam. Second, floods commonly lasting less than 24 hours (Alexander, 1990), are accompanied by an extremely short warning and response time, with potential for great loss of life (Gruntfest *et al.*, 1991).

The damaging effects of floods are complex. Floods frequently cause major infrastructure damage including disruption to roads, rail lines, airports, electricity supply systems, water supply and sewage disposal systems. Bridges over rivers are particularly vulnerable to damage and can cause disorders to the transport systems. The economic effects of floods are often much greater than indicated by the physical effects of floodwater coming into contact with buildings and their contents. Indirect economic losses typically spread well beyond the flooded area, and may last much longer than the flood itself (Parker and Neal, 1987). For example, loss of industrial or agricultural capacity or loss of communications can lead to major 'knock-on' effects, including loss of export earnings. The local and regional economy may be badly affected by a major flood disaster and this in turn may seriously affect the national economy especially where it is dependent upon a small number of flood-affected products.

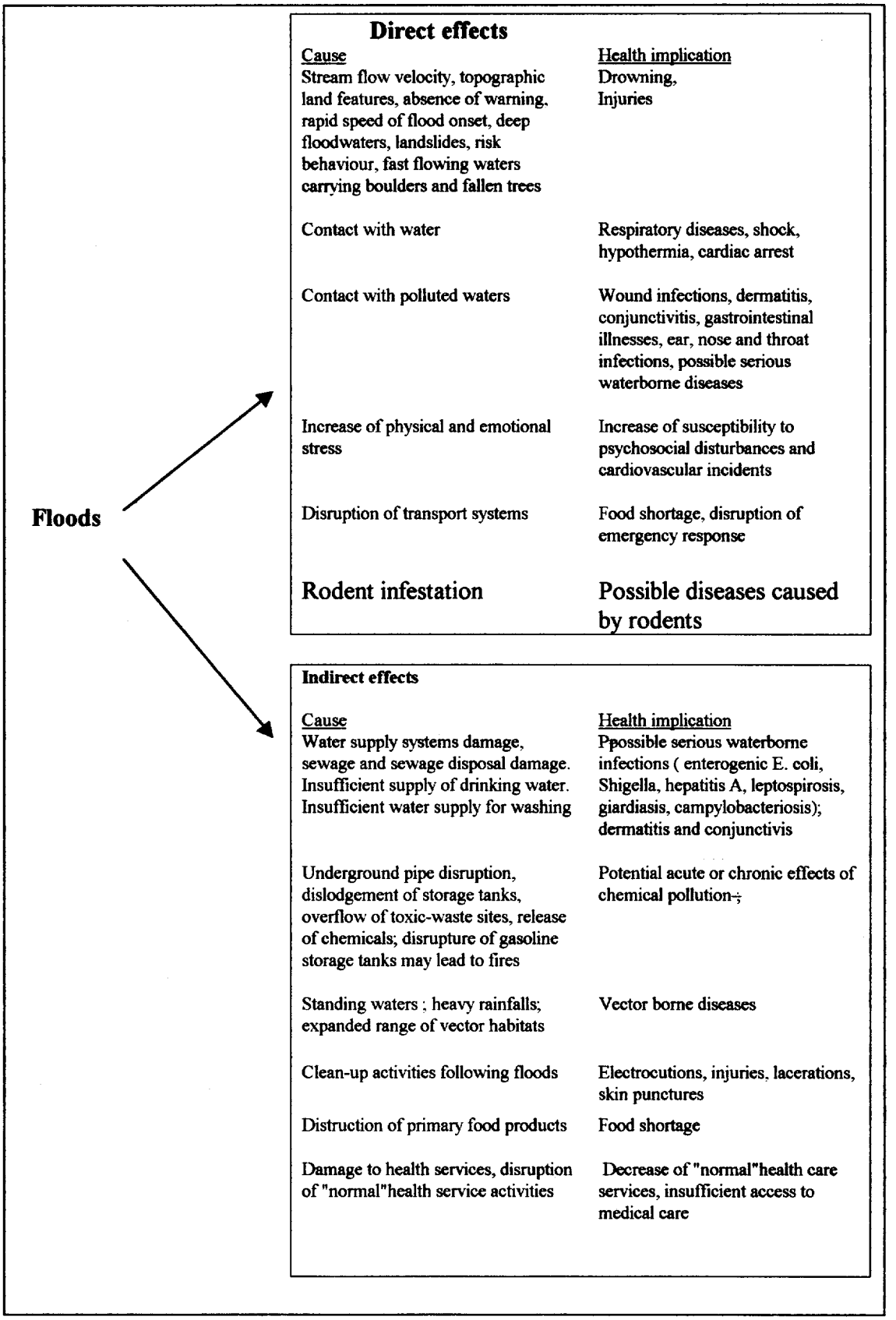
The vulnerability of economic and social activities to disruption of water supply, sewerage, or transportation systems, is related to their dependence upon those systems, transferability (the extent to which activities may be deferred in time or substitutes used) and the susceptibility of the systems to damage (Parker and Neal, 1987). For example, cities are particularly vulnerable to floods if they depend upon a single large water supply system. Similarly, remote areas that depend upon regular supplies transported by a single road are likely to be highly vulnerable to the direct effects of storm and flood damage on the road.

Floods may affect food availability in a number of ways. Food stocks may be damaged if storage areas are flooded. Serious flooding usually disrupts transportation of food and insufficient food supplies are likely in food-deficit areas, particularly towns, which are cut off from supply sources and have inadequate food stocks. If transport systems are disrupted for a long period, alternative routes or means of transport will be needed. Different problems may arise in regions where standing crops or stocks are destroyed especially where there is limited reliance upon outside food supplies. Such regions may have inadequate transportation systems to import food supplies and severe distribution problems may arise.

Public health impacts of flood disasters

The human health effects of floods may be divided into direct effects or indirect contributory effects as a result of being flooded (Figure 1).

Figure 1: The impact on human health of floods



Direct effects on health are those caused by the floodwaters. Indirect effects are those caused by other systems, which have been damaged by floods. However some of the health outcomes might be acute or short lasting, meanwhile others may be chronic or long lasting.

Characteristics of stream-flow velocity, waters carrying debris such as boulders and fallen trees can predispose residents and passers-by to risks of death or injuries. Landslides may occur secondary to flood disasters and exacerbate hazardous conditions (Diez *et al.*, 1990). Behavioural patterns and lack of awareness of the danger posed by fast moving floodwaters might also lead to death (CDC, 1993a). French (French *et. al*, 1989) has shown that flood-specific mortality varies by country. More than 90% of the studies in America have shown drowning as the first cause of mortality associated with flood events. In general, mortality due to drowning is frequently observed in flash flood incidents, when heavy water runoff inundates communities suddenly. Motorists in particular are at high risk of death when driving into swiftly moving water or when traffic is diverted by floodwater (Steas *et al.*, 1994; Gruntfest and Huber, 1991; CDC, 1993a; CDC, 1994). The majority of deaths from drowning in flood incidents occur among occupants of motor vehicles. Deaths may be in part attributed to misconception that motor vehicles provide adequate protection from rising waters. Vehicles, driven into water, become more buoyant because the momentum of water is transferred to the vehicle. Other contributory factors to death are related to the increased level of physical and emotional stress, which promote the likelihood of myocardial infection and even cardiac arrest among people with pre-existing heart conditions (CDC, 1993b). The number of deaths associated with flooding is usually closely related to the factors in Table 2, coupled with the behaviour of flood victims and the choices open to them (Green *et al.*, 1983).

Table 2 Life-threatening characteristics of floods

*	Absence of warning of a flood (either 'official' warning or warning derived from environmental cues e.g. heavy rain)
*	High floodwater velocities (likely in hilly or mountainous terrain or where streams disgorge onto plains from upland areas; in river valleys with steep gradients; in areas behind flood embankments or natural barriers which may breach or overtop, or below dams which may break)
*	Rapid speed of flood onset (likely in areas where streams are 'flashy' i.e. rise and fall rapidly; these are usually areas where soil surface becomes compacted and hard; or in areas where high floodwater velocities may be expected)
*	Deep floodwaters: where floodwater is in excess of 1 metre depth (occurs in or close to river channels; in depressions which may not be easy to identify by eye; behind overtopped flood embankments and in basements of buildings)
*	Long duration floods (likely where land is flat, flooding is extensive, river gradients are very low, channels are obstructed, and floodwater becomes trapped behind natural or artificial barriers)

* Flood has more than one peak (not untypical on complex river systems where tributaries contribute to river flows, or where flooding is tidal)

* Debris load of floodwaters (usually greatest in high velocity floods; floodwaters may contain trees, building debris etc which may either provide floating refuge or threaten life)

* Characteristics of accompanying weather (especially windy, unusually cold or hot weather)

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* Floods may display combinations of characteristics
Source: Parker and Thompson, personal communication

Among survivors of floods, the proportion of people requiring immediate medical care is reported to vary between 0.2% and 2%. Most injuries requiring immediate medical attention are minor, and include lacerations, skin rashes, and ulcers. However flood associated lacerations are frequently contaminated, therefore wounds should be carefully examined and cleaned.(Noji, 1995)

A further effect of floods upon health is the likely disruption of 'normal' health and social service programmes. Health and social services personnel are likely to be heavily involved in responding to the immediate and lasting impacts of disaster, thus removing them from their normal caring activities. Secondly, normal patterns of communication, either routine visits of health and social service personnel to districts, or visits of patients to hospitals or other care centres, is likely to be disrupted because of damage to transport systems. Thirdly, hospitals and other health and social service facilities may themselves be adversely affected by flooding or storm damage or their medical and other supplies may be interrupted, thereby temporarily reducing their capabilities. These problems might last also for months and even years.

Following the Bristol floods (UK, 1968) and Brisbane floods (Australia, 1974) there was a 53% increase in visits to general practitioners in the subsequent year following the floods. (Bennet, 1970; Abrahams, 1976)

The health effects deriving from indirect impacts arise from the affect on water supply systems including water purification plants, as well as sewerage and sewage disposal systems. There is also danger that toxic waste sites, storage tanks and chemical stores will be flooded or disrupted so that floodwaters may become contaminated with chemicals. Floods can also lead to overcrowding of homeless people.

There is a risk of increase in communicable disease following flooding, though severe occurrences are comparatively rare. An example is the outbreak of leptospirosis which occurred after the floodings in Recife, Brazil in 1975 and Czech Republic, 1997. There are also reports of outbreaks of scarlet fever in Moldavia, following floods (French and Holt, 1989). After flooding during a spring thaw in 1983, an outbreak of diarrhoeal diseases related to giardiasis was detected in Utah (CDC, 1983). After the heavy and intensive floodings in Sudan, endemic levels of hepatitis A and chloroquine-resistant malaria rose. Finally, epidemiologists attributed most deaths in Bangladesh in 1988 to nonspecific diarrhoeal diseases (Siddique *et al.*, 1991). Surveillance of arboviral diseases, such as St. Louis encephalitis and western equine encephalitis, was of concern after flooding in Midwestern and southern United States in 1993 and 1994. Standing water from heavy rains produced habitats for the proliferation of mosquito populations

that could have rapidly transmitted arboviruses. In this case surveillance indicated that the risk was minimal. There is an inherent risk of increased incidence of malaria following heavy rainfall and flooding. Mosquito populations are likely to multiply in the expanded range of habitats made available for breeding. Some European countries, such as Turkey, Azerbajan and Tajikistan are endemic for malaria.

The risk of disease is usually confined to disease normally endemic to the flooded region, and the risk of introducing new disease is small. Measles epidemics and respiratory infections sometimes occur in relief camps. There may also be diseases symptomatic of insufficient water for washing e.g. dermatitis, conjunctivitis and trachoma, gastrointestinal diseases. Some studies have shown that infectious disease outbreaks rarely occur and that mass immunisation programs for typhoid fever and cholera, commonly anticipated in the past, are unnecessary. (Dai, 1992; Blake, 1989; CDC, 1983). Nevertheless, the potential for transmission of water-borne diseases (e.g. enterotoxigenic *Escherichia coli*, *Shigellosis*, hepatitis A, leptospirosis, *giardiasis*) and for increased levels of endemic illnesses in flood-affected areas is possible.

Following the recent floods in the north-eastern Republic of Sakha (Yakutia) in July 1998, a high incidence of respiratory diseases was observed by the International Federation of Red Cross (IFRC) (IFRC, personal communication)

During the recent Oder floods, a high presence of rodents was observed (Kriz, personal communication), although no data are available or possible health effects have been studied.

In a flood, the potential for exposure to hazardous chemicals exists. Underground pipelines may rupture, storage tanks might be dislodged, toxic-waste sites may overflow, and chemicals stored at ground level may be released. Although, one study showed that toxic substances caused no health effects in a flash flooding in France (Siddique *et al.*, 1991) another showed that toxic substances presented a major concern for public health after extensive flash flooding and riverine flooding into the Mississippi river, its tributaries, and the Gulf of Mexico (Goolsby *et al.*, 1993). During the 1997 floods in Poland and the Czech Republic the ecological consequences included increased pollutant concentrations in the Oder estuary. Heavy metals, mineral oils and organic trace substances such as simazine and atrazine were carried by the flood waters. The nitrogen concentration was six times greater than the 1996 average and that of phosphate sixteen times the 1996 average. Little is known about the health effects (EEA, 1998). Fast flowing waters may break oil or gasoline storage tanks. If the film of oil is ignited, the fire may spread to buildings on land. (Noji, 1997)

In the aftermath of a flood disaster, physical injuries are likely to occur as residents return to dwellings to clean up damage and debris. Electrocutions have occurred from downed power lines, electrical wiring, and improper handling of wet appliances. Injuries from fire and explosions from gas leaks also occur when lit matches are used to inspect darkened structures for damage. Although minor in nature, lacerations and skin punctures are common outcomes because postflood debris often consists of broken glass and nails.

A number of investigators have reported increased ill health in flooded populations in the period following the flood disaster. Investigations show a consistent pattern of increased psychological problems amongst flood victims in the five years following floods (Green *et al.*, 1985). Longitudinal

studies have focused on the psychological consequences of flooding on individuals and communities. Studies show that severe psychological distress is rare, although small transient emotional problems are common. Subgroups, such as the elderly and the very young are probably at greater risk for psychological reactions (CDC, 1993). An increase in psychosocial symptoms and post-traumatic stress disorder including 50 flood-linked suicides were reported in the two months following the major floods in Poland in 1997 (IFRC, 1998). Data collected on suicides 36 months before a disaster and 48 months after disaster in the US showed a 13.8 increase of suicide rates following floods, from 12.1 to 13.8 per 100.000 ($p<0.001$) (Krug *et al.*, 1998). There are several reasons why people may commit suicide. The victims may be injured or may lose family members, friends, property or jobs, at least as important as the immediate consequences are the long-lasting alterations of day-to -day life and the disruption of social networks. Stores, bars, clubhouses, or churches-places were people found friends and support- may have been destroyed. Factors such as bereavement, property loss, and the disruption of social networks have been associated with mental health problems. (Krug *et al.*, 1998).

PREVENTION AND CONTROL MEASURES

The severity of flood disasters is largely affected by the timing of phases in which a flood event takes place. Before, during and after a flood event activities may be undertaken by the population at risk, by policy makers and by emergency responders at each phase in order to reduce the risk of injuries, illness or death. The underlying information, which is necessary in order to establish the most appropriate actions to be taken, depends on the background knowledge of the territory.

Preventive measures in public health, foreseen:

1. *Primary prevention*: are actions taken to prevent the onset of disease from environmental disturbances, in an otherwise unaffected population (e.g. mitigation, early weather watch warning systems).

2. *Secondary prevention*: preventive actions taken in response to early evidence of health impacts (e.g. disease monitoring and surveillance).

3. *Tertiary prevention*: health-care actions taken to lessen the morbidity or mortality caused by the disease (e.g. access to diagnosis and treatment; emergency response).

Mitigation

In the past, mitigation (i.e. the reduction of the harmful effect of a disaster by limiting the disaster's impact on human health and economic infrastructure) measures have been used in the traditional fields of engineering and urban planning. Currently these measures refer to structural or policy-oriented modifications that can be made independently of a disaster event. Those measures include building codes, promulgating legislation to relocate structures away from flood-prone areas, planning appropriate land use and managing costs of floodplains. Adequately designed flood-control structures such as levees and floodwalls offer protection; however, as the flooding in the American Midwest during 1993 showed, these structures can fail from time to time. Some attempts have been made in the Americas to 'buyout' homes from flood prone areas in order to convert those areas. Despite these attempts, human settlements in these areas are growing. However, in Europe, the initiative " Raum fuer den Rhein (room for the Rhein) regulates the use of the area between the dikes and the river Maas and Rhein. (Leitlinie, Raum fuer den Fluss, April, 1997)

Warning

Early detection and appropriate citizen's response to these warnings have been shown to be effective in reducing disaster-related deaths. In the USA weather forecast and warning systems have enhanced public safety during floods events. Likewise several countries have also implemented severe weather watch and warning programs that allow officials to take appropriate emergency management actions such as evacuation and sheltering. In general these systems consist of two components: watches are issued when meteorological conditions indicate that severe weather may affect the area and if the meteorological conditions create threats to human life and property, watches are upgraded to warnings (Belville, 1987).

Broadcasts should be issued to warn the population. Appropriate educational messages are critical in preventing deaths, injuries and illness. Therefore the design of effective messages with desirable behavioural outcomes are essential to broadcast together with the weather warning.

From a public health point of view planning for floods during the inter-flood phase aims to create the conditions necessary to allow disaster relief operations to achieve the following objectives.

- To enable communities to effectively respond to the health consequences of floods.
- To enable the local and central authorities to organise and effectively coordinate relief activities, make best use of locally available resources and properly manage eventual international relief assistance (WHO, 1995).

During planning, several emergency management actions should be implemented (WHO, 1995):

1. Mapping of potential risks, the estimated frequency, location of chemical and nuclear plants and other hazardous sources, location of dwellings, location of public buildings and transport systems at risk, etc.
2. Vulnerability analysis, taking into account population density, vulnerable structures, economic aspects, etc. The traditional mechanisms for coping with floods should be carefully evaluated, and included into the preparation and contingency planning.
3. Inventory of existing resources, including infrastructure, personnel, communication, transport, health services, medical stocks, etc. in order to facilitate the rapid mobilisation of all available resources. The inventory should be frequently updated, including resources available from NGO's, the private sector and the army.
4. Preventive measures in the health sector include preparedness in medical supply management.
5. Establishment of a regional or national co-ordination mechanism including the health sector.

Disaster preparedness and response:

The objectives of disaster preparedness and response activities in the health sector can be expressed as follows:

- To prevent excess mortality from floods;
- To provide appropriate and timely care for casualties due to the disaster;
- To prevent exposure to specific environmental conditions (lack of food, clothing, etc.);
- To prevent short term and long term related morbidity;
- To re-establish health services to pre-disaster levels.

Several specific issues are germane to public health during and immediately after the floods. These include water quality; food safety; sanitation and hygiene; precautions during clean-up activities; potential immunisation as determined by local health officials (e.g. administering tetanus vaccine to those with lacerations if indicated by the injured person's tetanus immunisation history); protective measures against potential vector borne diseases; chemical hazards and mental health well being measures, such as stress reduction and counselling for both the victims and responders. When flooding occurs, local health departments will need to focus on obtaining information about emergency requirements, delivering

services or supply to community needs. A guide to good practice compiled from previous experiences of flood management might be very useful to local health authorities.

In some cases, such as sudden impact flooding a rapid need assessment should be conducted in order to determine the health and medical needs of communities. (Maylay, 1997; CDC, 1993) A rapid needs assessment is a qualitative assessment by a random questionnaire or focus groups, that addresses the health status, medical and pharmaceutical needs, status of public health services, conditions of water supply, sewage system and electricity supply.

A major activity during and after a flood is public health surveillance of mortality and morbidity associated with disasters. Mortality surveillance is performed to determine the nature and circumstances surrounding deaths caused by floods, in order to prevent further mortality. Morbidity surveillance is conducted to determine any increase of disease endemic in the area, any increase of infectious diseases that must be contained or controlled and any cases of injury that may require public advisories or controls of animal or vector populations. Laboratory analysis of public and private wells should also be part of surveillance as well as increases in vector populations. In order to establish surveillance activities a clear definition of flood- related deaths, or illnesses is required. This definition will vary from country to country, but should include those diseases, which possibly will occur in the flooded area. The length of time that the surveillance system should operate for and the sources of reporting should be established. Results for the flood surveillance should be compiled, analysed and disseminated to decision-makers, on a regular basis.

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