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Monographic issue

An approach to the disaster profile of People's Republic of China 1980-2013

Emma Van Rij

University of Oviedo – Department of Medicine
Unit for Research in Emergency and Disaster

Letter from the editors

The *Emergency and Disaster Reports* is a journal edited by the Unit for Research in Emergency and Disaster of the Department of Medicine of the University of Oviedo aimed to introduce research papers, monographic reviews and technical reports related to the fields of Medicine and Public Health in the contexts of emergency and disaster. Both situations are events that can deeply affect the health, the economy, the environment and the development of the affected populations.

The topics covered by the journal include a wide range of issues related to the different dimensions of the phenomena of emergency and disaster, ranging from the study of the risk factors, patterns of frequency and distribution, characteristics, impacts, prevention, preparedness, mitigation, response, humanitarian aid, standards of intervention, operative research, recovery, rehabilitation, resilience and policies, strategies and actions to address these phenomena from a risk reduction approach. In the last thirty years has been substantial progress in the above mentioned areas in part thanks to a better scientific knowledge of the subject. The aim of the journal is to contribute to this progress facilitating the dissemination of the results of research in this field.

This last number of 2016 of the Emergency and Disaster Reports is a general approach to the disaster profile of China. The People's Republic of China is a country that suffers high losses from disasters, in terms of human life as well as socioeconomic losses. This disaster risk profile was developed in order to provide an overview of the risks that China faces, including probability of different types of hazards; vulnerability from exposure due to geographical, topographical and socioeconomic factors; and existing policies and strategies for disaster risk reduction.

The risk profile presented here is based on historical information of disasters and previous research on vulnerability and risk factors. Due to the extensive amount of literature and data on natural disasters, the majority of this report focuses on these disasters, although it is recognized that technological disasters are equally important and require more attention in future research.

Prof. Pedro Arcos, Prof. Rafael Castro
Editors, Emergency and Disaster Reports
Unit for Research in Emergency and Disaster
Department of Medicine. University of Oviedo
Campus del Cristo 33006 Oviedo – Spain
www.uniovi.net/uied

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Author: Emma Van Rij

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1 Introduction

The People's Republic of China (henceforth called China) is a country that suffers high losses from disasters, in terms of human life as well as socioeconomic losses. This disaster risk profile was developed in order to provide an overview of the risks that China faces, including probability of different types of hazards; vulnerability from exposure due to geographical, topographical and socioeconomic factors; and existing policies and strategies for disaster risk reduction.

The risk profile presented here is based on historical information of disasters and previous research on vulnerability and risk factors. Due to the extensive amount of literature and data on natural disasters, the majority of this report focuses on these disasters, although it is recognized that technological disasters are equally important and require more attention in future research.

1.1 Background & Context

China is one of the countries that suffer the most natural disasters. Natural hazards strike not only with high frequency, but the country also suffers from a large diversity of hazards, including typhoons, earthquakes, floods, landslides and droughts. Natural disasters in China have affected on average the lives of at least 90 million people annually since the 1980s and have caused large economic losses.

The average annual economic damage caused by natural disasters is estimated around 11 billion US$. Overall, the most frequent disasters are storms and floods, followed by earthquakes. However, the occurrence of disasters varies greatly per region. Earthquakes are responsible for the largest proportion of people killed by natural disasters (58.8%), but floods account for the most people affected (64.0%). [1]

In addition, China faces many technological disasters, of which industrial accidents are the most common. [2] However, there is a lack of reliable data when it comes to technological disasters. Although reports can be found in disaster databases and in news items, these are likely to be underrepresenting the actual impact. Environmental and safety hazards are becoming more frequent and are occurring on a larger scale.

Both the Chinese government and the corporations involved seem to prevent or delay media attention to these hazards. This lack of information also makes it possible for technological hazards to keep happening, because lessons learned from recent disasters are not spread. [3]

Due to the lack of data, and a lack of policies for reduction of technological disasters, this report mainly focuses on natural disasters. Nonetheless, one should bear in mind that the impact of technological disasters in China is all but negligible, and if no action is being taken, the combined impact may even exceed that of natural disasters.

Natural disasters seem to become more frequent. In recent years, earthquakes have occurred more frequently and with higher magnitudes than expected. [4] But hydro-meteorological disasters such as floods and cyclones are also becoming more frequent. [5] In the first half of 2013 alone, 782 people have been killed in China as a result of natural disasters and more than 150 million people have been affected. The most severe disasters occurred in the southwest of the country, a major event being a 7.0-magnitude earthquake in Sichuan province, which killed 196 people. [6]

While people still die in China because of natural disasters, the number of deaths has clearly declined over the past century. The deadliest event since 1980 was an 8.0-magnitude earthquake in Sichuan province in 2008, which caused more than 87 000 deaths. Although this is a huge number and it was the most devastating earthquake since 1976, this quake does not appear in the top 10 deadliest events since 1900.

In fact, with the tenth deadliest event causing 142 000 deaths, there is still a big difference between that and the 2008 earthquake. Moreover, this earthquake has been an exceptionally deadly event in the last three decades, which is shown by the fact that the second deadliest event since 1980 was a flood that killed 3 656 people. [2]

So it seems that China is on the right track when it comes to decreasing the number of natural disaster-related deaths. However, an opposite trend is visible when it comes to both the number of people that are affected by disaster, and the economic damage disasters cause.

The top ten events since 1900 in terms of number of people affected and economic damage, all have occurred since the late 20th century. [2] This suggests that although the number of disaster-related deaths is decreasing, more people are being affected by disaster and the economic damage is increasing. This might be due to China's recent economic and demographic development.

1.2 Country Overview

The large variety of natural disasters that China faces, is partially due to its geography and demography. With a surface area of more than 9.5 million km^2 it is the fourth largest country in the world. It has a coastline of 14.500 km along the east and south of the country. In the west, the terrain is mostly made up of mountains, deserts and high plateaus, whereas in the east one will find hills, deltas and plains.

The extensive area also gives rise to a very diverse climate: from subarctic in the north to tropical in the south. A factor that contributes to China's vulnerability to natural hazards is its demography. It is the most populated country in the world, with a total population of almost 1.4 billion people, of which more than half live in urban areas. There are a number of multimillion cities in China, of which Shanghai and Beijing are the largest, with 16.5 and 15.5 million inhabitants, respectively. [7]

Figure 1 Provinces of China (source: sacu.org)

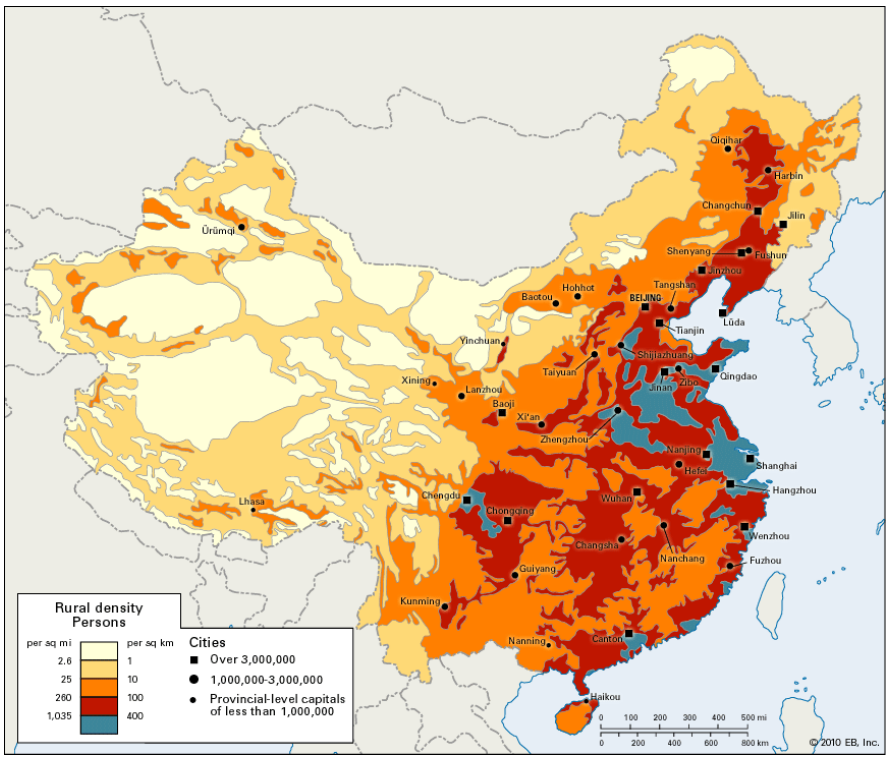


Figure 2 China population density (source: brittannica.com)

2 Methodology

2.1 Concepts

Throughout this report a number of technical terms are used. For the most important terms the following definitions from the United Nations International Strategy for Disaster Reduction (UNISDR) [8] and the Centre for Research on Epidemiology of Disasters (CRED) [9] have been used for reference.

2.1.1 Disaster

A disaster is 'a serious disruption of the functioning of a community or a society involving widespread human, material, economic of environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources'. [8] In order for an event to be included in the CRED database, it must fulfil at least one of the following criteria: 1) ten or more people reported killed; 2) hundred or more people reported affected; 3) declaration of a state of emergency; or 4) call for international assistance. [9]

2.1.2 Exposure

Exposure is understood as the 'people, property, systems or other elements present in hazard zones that are thereby subject to potential losses'. [8] For all natural disasters goes that human impact is generally higher in those areas with high population density, including the south-western, central and eastern provinces of China. Absolute direct economic losses are especially high those provinces with a relatively strong economy, such as the eastern coastal provinces. However, at the same time their capability against disasters is greater, which leads to a lower percentage of direct economic loss. In areas where the resistant capability to natural disasters is weak, the relative loss ratio is higher. [10]

2.1.3 Vulnerability

Vulnerability includes 'the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard'. [8]

2.2 Data collection

This report is a review of available literature and databases on disasters in China. The EM-DAT database of CRED [2] has an extensive amount of data on natural disasters in China, and to a lesser extent on technological disasters. Therefore, this database was used as a primary source for the data presented in this report. In addition, other sources were used to support or contradict the information found in EM-DAT, such as research articles, reports from various institutions of the United Nations, official government documents, news articles, and situation reports provided by international actors in humanitarian action. These articles and documents were obtained through searches in different search engines, including PubMed, Science Direct, Directory of Open Access Journals, Reliefweb, Google and Google Scholar.

3 Discussion of natural disasters since 1980

As mentioned before, China faces a large variety of natural hazards. This section will discuss the risks for the ones that are most common and that have the greatest impact. In the years 1980 to 2013, the most frequent natural hazards reported were storms, which occurred 224 times. Storms were followed by floods, with 218 events, and earthquakes occurred 117 times. Other hazards that have been reported, though to a lesser extent, include mass movements (both wet and dry), droughts, extreme temperature, epidemics and wild fires. [2]

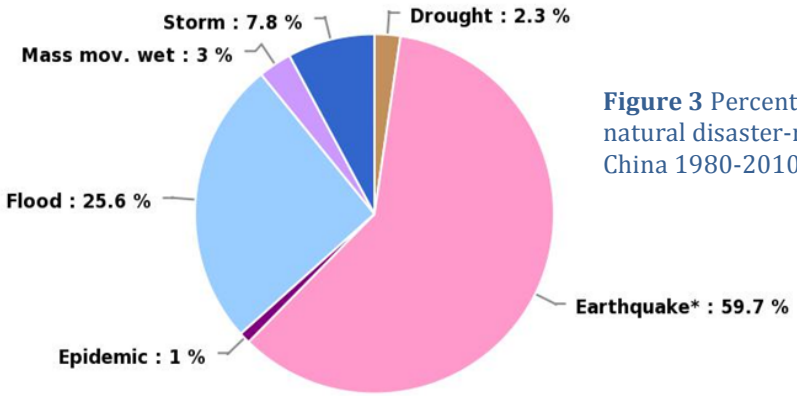


Figure 3 Percentage of reported natural disaster-related deaths in China 1980-2010 [1]

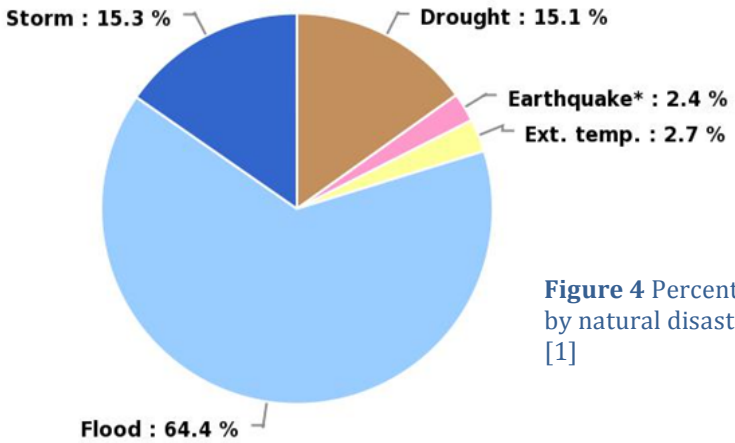


Figure 4 Percentage of people affected by natural disaster in China 1980-2010 [1]

Earthquakes account for the largest number of people killed, with a total of 92 829 deaths, but floods and storms have also led to a large number of deaths, 39 804 and 12 186, respectively. However, when it comes to the number of people affected by disasters, floods have by far the greatest impact, affecting more than 1.7 billion people in 30 years. This is two times the number of people affected by earthquakes and storms together in that same period of time. [2]

3.1 Earthquakes

An earthquake is the displacement and shaking of the ground due to seismic waves, usually caused by the rupture of a geologic fault when two tectonic plates suddenly move in a different direction. An earthquake's intensity is generally measured according to two scales. The first is the Richter scale, which reports the magnitude of earthquakes by measuring seismic waves on a logarithmic scale of 0-8.0, where 8.0 is the maximum and an earthquake of this magnitude causes total destruction. Any earthquake of a magnitude of 6.0 or more on this scale can cause severe damage in populated areas. The second way of reporting the severity of an earthquake is the Mercalli Intensity Scale. This is somewhat more subjective as it relies on the perception of the people that experienced the earthquake, and on the damage it has caused. This scale is from I-XII, where XII causes total destruction. [11] Since 1980, a total of 117 earthquakes have occurred in China, with different magnitudes and in a wide variety of locations. [2]

3.1.1 Historic events

According to the China Earthquake Network Centre, China is currently experiencing more earthquakes than have been reported in history. In the first half of 2013 the Chinese Ministry of Civil Affairs had already reported 21 quakes of a magnitude more than 5.0, which is much more than expected. [4] So far in 2013, China has experienced 2 severe earthquakes, with a magnitude of >6.0. They occurred in south-west and north-west China: in Sichuan and Gansu province, respectively. [12]

The earthquake in Sichuan province occurred on April 20th with a magnitude of 7.0, and in the following days 4000 aftershocks have been reported, of which 100 with a magnitude of more than 3. A total of 196 people have been killed, 14 785 people were injured, and 237 665 were displaced. The earthquake severely damaged 510 000 houses, and another 193 000 houses collapsed. The quake affected a total of 2.1 million people. Roads had been blocked and electricity and water supply interrupted. Within less than 20 minutes an earthquake-relief centre had been established by the Chengdu military region, and the Chinese government issued a class 1 disaster response.

NGO rescue forces were also involved. A total of 18 000 troops were sent to the affected region for rescue. [12,13,14] On July 22nd, a 6.6 earthquake hit the north-west of Gansu province. 94 people were reported dead, 628 injured and 225 000 people needed to be relocated. The Ministry of Civil Affairs and the National Committee for Disaster Reduction launched an emergency response and sent teams to the affected areas. [12,15]

According to the EM-DAT international disaster database by CRED [2], 117 earthquakes have been reported since 1980, of which 68 (or 58%) have resulted in human casualties. There is a clear increase in the number of quakes reported, with 17 occurring from 1980-1989, 31 between 1990 and 1999, 46 from 2000-2009, and between 2010 and 2013 the number has already totalled 23. However, this

may also reflect improvement in the reporting of earthquakes, rather than an actual increase in the numbers.

There is no clear trend in the number of quakes that lead to the death of people, but there seems so be a decrease in the number of people that are killed in earthquakes. Between 1980 and 1989, the average number of deaths per earthquake was 74. Between 1990 and 1999, this number had decreased to only 21.

The period 2000-2009 gives a different picture, with an average of 1912 people killed per earthquake. However, this high number is mainly the result of one particular earthquake: the 2008 quake in Wenchuan county, Sichuan province, which is among the ten most devastating earthquakes since 1900, in terms of the number of people that were killed and the number of people affected, as well as in economic damage. Taking this quake out of the equation, results in an average of 10 people killed per event between 2000 and 2009. [2]

China's earthquakes have an evident spatial distribution. Since 1980, by far the majority of earthquakes have occurred in the west and south-west of the country, especially in three provinces: Xinjiang, Yunnan and Sichuan province. Other provinces that have been struck by earthquakes multiple times, are Gansu, Inner Mongolia and Qinghai in the north, Tibet in the west, and a number of provinces along the eastern coast, among others Shandong, Hebei and Liaoning.

The most severe earthquakes, in terms of people affected or killed and economic losses, tend to occur in the three provinces that are also most frequently hit. The most devastating earthquake since 1980 is the 2008 Wenchuan earthquake in Sichuan province, which will be discussed in more detail later. Another especially deadly event occurred in April 2010 in Qinghai province, when 2968 people were killed. This earthquake had a magnitude of 6.9. More than 12 000 people were injured, and it has left thousands of people homeless due to the collapse of mostly wood-earth houses. This event has affected 112 000 people, and the economic damage was estimated at 500 million US$. In addition, the region was difficult to reach for response teams, since it lies at an altitude of 3 7000 meters and most of the few roads leading to the affected villages had collapsed. [16,17]

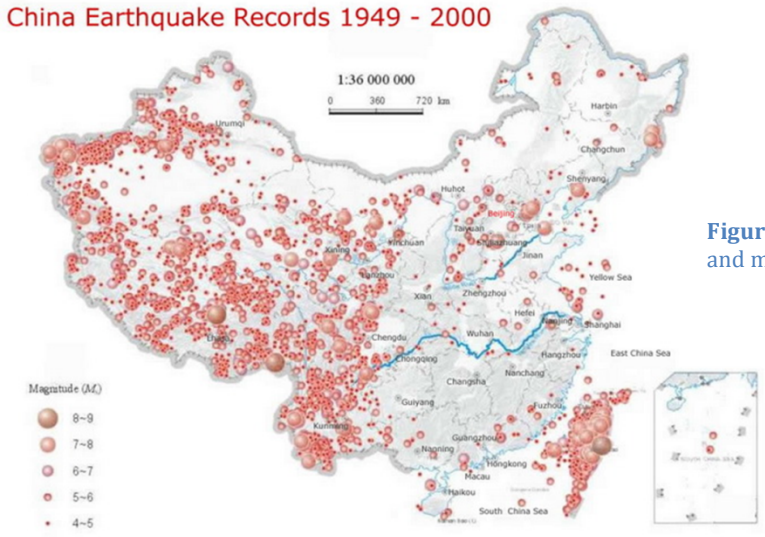


Figure 5 Distribution of earthquakes and magnitudes 1949-2000 [19]

The earthquakes that affect the largest number of people have mainly happened in Sichuan and Yunnan province, which have experienced eight earthquakes that affected more than a million people each, some even several million. A major event also occurred in Shanxi province in November 1999. Although no one was killed, the earthquake affected more than 3 million people. Also in terms of economic damage Sichuan, Yunnan and Xinjiang province were in the lead during the past decades. Sichuan has suffered the most damage recently, with an estimated 6.8 and 85 billion US$ loss in the earthquakes of April 2013 and May 2008, respectively. [2]

3.1.2 Exposure and vulnerability

As has been shown above, China is a country that faces many earthquakes. It is located on the Eurasian tectonic plate, which meets the Philippine plate along the eastern coast and Taiwan. The Indian plate is involved in the Himalayas. The collision of the Indian plate into the Asian plate is primarily responsible for the seismic activity in China. As the Indian plate moves towards the north, it pushes the Tibetan plateau out of its way, towards the east, which is causing deformation in the crust of the rest of the Chinese territory. It is this deformation that leads to the many earthquakes in the west and south-west of China, including the great 2008 earthquake in Sichuan province. [18]

Most provinces have been exposed to earthquakes, and are therefore at risk for future quakes. However, the magnitude and frequency show a spatial pattern. Earthquakes with a magnitude of more than 6.0 have mainly concentrated in south-west China, but also occurred more widespread across central and western regions. However, occasionally large earthquakes have hit provinces in the north-east.

The great majority of quakes of lower magnitude also occurred in the south-western and western provinces (figure 3). [19,20] When looking at the country as a whole, according to the China Earthquake Network Centre, China experiences around 20 earthquakes with a magnitude between 5.0 and 5.9 annually and 3 to 4 between 6.0 and 6.9. Earthquakes with a magnitude more than 7.0 occur on average every two or three years. [4]

Important factors in China's vulnerability to earthquakes are its buildings and infrastructure. Especially in urban areas, where most residential buildings are made from concrete and brick, the main danger comes from collapsing buildings and falling debris. This threat is increased by the fact that many buildings in Chinese cities are high-rise. However, since the 1990s codes for construction and planning have been specified, leading to higher levels of earthquake-resistance and construction standards.

Since most buildings are fireproof, the spreading of fire does not usually pose a threat in case of earthquakes. [21] Damage to and collapse of buildings are mainly

responsible for the loss of lives and injuries, it often leaves people homeless and causes direct economic loss. Indirect economic loss mostly comes from industries that are forced to stop their operations due to physical damage. Damage to public infrastructure often leads to disruptions in power and water supply, telecommunications and blocked roads. For big cities, the amount of damage usually decreases as the distance from the epicentre increases. However, for smaller towns and villages this correlation is not as pronounced, due to lower construction quality and therefore lower seismic resistance. The danger posed by earthquakes can be limited by building structures that can withstand earthquakes and will retain sufficient structural integrity to avoid collapse. [22]

Potential impacts on public health in China are similar to those in other countries. Morbidity comes mainly from injuries that are a direct result of structural damage due to the earthquake. Fractures are the most common injury, and many occur in the extremities. [23]

Psychosocial damage is another important effect, but the extent of damage will partially depend on coping strategies such as religion. An indirect threat to epidemics comes from possible disruption of food and water security and environmental safety. This threat is increased by the displacement of populations as a result of damage to residential buildings. In China, measures generally are in place to prevent this from happening. [24]

3.2 Floods

Although there are several types of floods, the great majority of floods occurring in China can be classified as general floods: 'gradually rising inland flood (rivers, lakes, groundwater) due to high total depth of rainfall or snowmelt. A general flood is caused when a body of water (river, lake) overflows its normal confines due to rising water levels.

The term general flood additionally comprises the accumulation of water on the surface due to long-lasting rainfall (water logging) and the rise of the groundwater table above surface. Furthermore, inundation by melting snow and ice, backwater effects, and special causes such as the outburst of a glacial lake or the breaching of a dam are subsumed under the term general flood.

General floods can be expected at certain locations (e.g. along rivers) with a significantly higher probability than others'. [25] These floods are generally of long duration, they can last up to several weeks or even months if rainfall continues. Another type of floods that occurs in China, although they are less frequent, is flash floods. These are sudden and of short duration, typically associated with thunderstorms. On a slope, the water moves rapidly and has a high potential for destruction. On flat terrain, the water cannot run off or infiltrate the ground as fast as it falls. [25]

3.2.1 Historic events

Floods occur most frequently in South- and East-China. Since 1980, 218 floods have been reported, most of them occurring in provinces in eastern and south-

eastern China, although virtually all provinces have experienced at least one flood during the past three decades. Together, these floods have caused almost 42 000 deaths, and have affected a total of more than 1.9 billion people, of which close to 40 million have been rendered homeless, making floods responsible for by far the largest share of people affected by natural disasters. In addition, floods have caused a total damage of almost 200 billion US$ in China since 1980, which corresponds to 48% of the total economic damage caused by natural disasters. [2]

Table 1 Top 10 natural disasters in China since 1900 sorted by number of people affected [2]

Disaster	Date	No Total Affected
Flood	1-7-1998	238973000
Flood	1-6-1991	210232227
Flood	30-6-1996	154634000
Flood	23-6-2003	150146000
Flood	29-5-2010	134000000
Flood	15-5-1995	114470249
Flood	15-6-2007	105004000
Flood	23-6-1999	101024000
Flood	14-7-1989	100010000
Storm	14-3-2002	100000000

Although floods are not responsible for the largest share of deaths due to natural hazards in China (the 42 000 deaths correspond to 26% of all natural disaster-related deaths, whereas earthquakes are responsible for 58%), many floods have caused an exceptionally high number of casualties, resulting in an average number of deaths per event that is much higher than it is for earthquakes. Between 1980 and 1989, an average of 373 people died per flood. This was mainly due to two periods of heavy flooding. In June 1980, three provinces in central and eastern China were severely affected by floods.

In Sichuan, Hubei and Anhui provinces the death toll rose to 6000. In July 1989, the Yangtze River in Sichuan province was flooded due to torrential rain for several days. The maximum rainfall reported was 500mm. Provinces downstream of the river were also affected. Additionally, the heavy rains led to landslides, which in turn increased the number of casualties and the amount of damage. These floods led to a total of 2000 deaths, more than 10 000 people injured, and 100 million people affected, spread out over at least six provinces in the east of the country. [2,26]

In the period between 1990 and 1999, the average number of people killed per flood still remained high at 390. In this decade, a number of events caused more than 1 000 deaths, but two cases were especially deadly. In July 1996, eastern China was again hit by prolonged and heavy rain. Many rivers overflowed. Hubei,

Hunan and Guangxi province were the most severely hit. 2.7 million houses were completely destroyed, more than 14 million were severely damaged, and almost 9 million hectares of crop area were affected.

A total of 155 million people were affected by these floods, of which more than 4 million were evacuated in the three most seriously affected provinces. [2,27] Only two years later, during the summer of 1998, China experienced one of its worst floods. 3 656 people died, making it one of the deadliest disasters since 1980. With a total economic damage of 30 billion US$, it is one of the most costly disasters of China, and even the number one in terms of people affected, which totalled to almost 239 million people.

During that summer heavy rain fell in several regions of China. This, in combination with human factors such as deforestation of the river basin, again caused the Yangtze river to flood, affecting Hubei, Hunan and Jiangxi provinces in the south-east. Other factors that contributed to the magnitude of this disaster are the inhabitation of vulnerable flood plains and neglect of the dykes. Water levels rose up to 6m, submerging more than one million hectares of crops and hundreds of thousands of houses for more than two months. In the same period, north-eastern provinces were also hit by extreme rainfall.

In total, the floods left 14 million people homeless, and damaged 25 million acres of crops. Although external assistance was needed due to the extent of the disaster, the Chinese government handled the situation in a very efficient way. Basic temporal shelter was provided, all accessible people received basic food items and medical care, temporary schools had been set up and started on the 1st of September, and no large scale disease outbreaks occurred in the camps. [2,28,29,30]

In the beginning of the 21st century, deaths by floods seem to be decreasing. The event that caused the highest number of deaths, were the floods in June 2002, once more affecting the Yangtze river and the provinces in the south and east of China and killing almost 800 people. This time more than 80 million people were affected. Some 600 000 houses were destroyed, 1.5 million people were displaced and millions of hectares of farmland were demolished.

The affected areas again received assistance from the international community to cope with the situation. [2,31] In the summer of 2007, 24 of China's provinces experienced floods due to heavy rainfall. The most severely hit areas were in the south and included minorities and impoverished communities, especially farmers, from the mountains in Guizhou province, along the Huai river in Anhui province, and along the Yangtze river in Sichuan, Chongqing and Hubei provinces.

Nearly 5 million people were evacuated. In many areas these floods were described as the worst in more than a century, and in some cases even as the worst in history. [32] The general floods were accompanied by landslides and flash floods, and a heat wave made the situation even worse for those living in temporary shelters. Overall, more than 500 people were killed, and numbers of people affected vary between more than 100 million by CRED and up to 200

million according to other sources. [2,33] The damage was estimated at 4.4 billion US$. [2]

Of the top 10 natural disasters in terms of total affected people that occurred in China since 1900, 9 are floods, and all of them occurred after 1980. With few exceptions, the most deadly floods mentioned here are also among the 10 floods that affected the largest numbers of people. All of them occurred in southern and eastern China, the provinces along the Yangtze River being the most often affected. [2]

The same goes for the most costly floods, except for one event, which is the fifth most economically damaging flood China has seen since 1980. In July 2012 many parts of China were affected by flooding due to heavy rain, including parts of Beijing, which experienced the heaviest rainfall in sixty years. An important factor in Beijing's floods was the outdated sewer and drainage system, of which the development has not been keeping up with the rapid urban development. The economic damage across China totalled 8 billion US$ in that month. [2,34]

3.2.2 Exposure and vulnerability

Geographically, floods occur most in China's eastern and southern provinces. Most affected are especially the provinces along the Yangtze River. Floods are often seasonal, as they coincide with the rainy season, and with occurrence of typhoons in the coastal provinces. Increased exposure to floods is related to high intensity land use.

Large urban areas are exposed to floods, as they can be located in proximity to large rivers or lakes that are at risk of flooding in case of heavy rain, as well as agricultural areas, since most of the arable land is located in flood plains. Although loss of lives due to flooding seems to be decreasing, many people still lose their houses or are affected in another way. In general, residential buildings are more vulnerable to floods than commercial and industrial buildings. These concrete constructions are more resistant to water damage than residential wood-frame buildings. [35]

Mortality due to flood is mostly attributed to drowning or trauma, such as injuries from objects in flowing water. Injuries may also occur when people try to remove themselves, others or possessions from danger, or when they return to the affected buildings to clean up. Faecal-oral diseases can be an indirect effect of floods, due to disruption in safe water and sanitation provisions.

Vector-borne diseases may decrease initially, because breeding sites are washed away. However, in situations where stagnant water remains due to for example blockage in the draining system, there may be an increase in transmission. Floods can also have an impact on the mental health of the affected population. Especially common mental disorders such as depression and anxiety tend to increase, as well as post-traumatic stress disorder. One study even shows that one of China's areas most prone to flooding has an increased suicide rate, although there is no evidence for a direct relationship between suicide and flooding. [36]

China's agriculture is often affected by floods, as much of the arable land is located in floodplains, resulting in a large number of affected people, but also in direct economic losses. However, although crops can be lost locally due to floods, overall floods usually cause relatively minor crop losses, because the amount of cropland that benefits from the additional rain is often larger than the amount that is damaged. This goes especially for crops like rice. Other types of crops, such as cotton, are more vulnerable to excessive rain and suffer greater losses. [37]

China's flood loss potential is increased by its industries at risk. 52% of its industrial areas is exposed to flooding. Many of these industries are driven by foreign direct investment, which is concentrated in mainly three sectors: electronics, machinery and manufacturing, and retail and wholesale. These are occupancies that are very vulnerable to water. The most exposed region, the Pearl River delta in the south-east, could cause insured losses up to 44 billion US$. [38]

Additional factors influencing the extent and intensity of the floods are human-made. Deforestation results in soil erosion, as a consequence rain can wash off the top soil, which ends up in the river bed and raises the level of the water. This in turn makes the river more prone to flooding. [39] Desertification and drought are also a risk factor for floods, as this decreases the land's ability to conserve water. [40] On the other hand, dams can be constructed to control flooding in downstream areas. The Three Gorges Dam in the Yangtze River is an example. It was built as a flood control measure, trying to minimise the impact of devastating floods by limiting the amount of water that flows further downstream. Therefore, it is a measure that decreases the vulnerability of downstream regions. [41]

Another aggravating factor is climate change. Although heavy rain is still more frequent in the south than in the north of China, there is a trend that the north is experiencing more and stronger rainstorms than before. Increasing temperatures due to global warming result in more water vapour and heat exchange, leading to more frequent precipitation.

Although it is not yet sure whether there is a direct relationship between climate and changing weather events, China should prepare for more frequent and widespread flooding. An important measure is to improve drainage systems, especially in urban areas. Many systems in cities such as Beijing are not capable of withstanding the type of heavy rainstorms that may occur in the future. [42]

3.3 Storms

Storms are the most frequent natural hazard in China. 224 storms have been reported by CRED since 1980, corresponding to more than six storms per year on average. Between 1980 and 2013, a total of 12 470 people were killed in storms, which is almost 8% of all natural disaster-related deaths. Storms have the second largest impact in number of people affected, after floods, with 478 million in total. [1,2]

Most of China's storms can be classified as tropical cyclones, especially among those taking the most lives and causing the most economic damage. However, many can also be called more general local storms, which are caused by regional

atmospheric phenomena that are typical for that area and that can come along with high winds, heavy precipitation, thunder and lightning.

‘ tropical cyclone is a non-frontal storm system that is characterised by a low pressure centre, spiral rain bands and strong winds. Usually it originates over tropical or sub-tropical waters and rotates clockwise in the southern hemisphere and counter-clockwise in the northern hemisphere. The system is fuelled by heat released when moist air rises and the water vapour it contains condenses.’ [25] Since China borders the western Pacific, its tropical cyclones are called typhoons.

3.3.1 Historical events

Since 1980, the EM-DAT database has shown an increase in the number of storms reported in China. Whereas only 37 storms were reported between 1980 and 1989, this number almost doubled in the following decade, when 73 storms were reported. The number continued to rise in the first decade of the 21st century, to 85. [2]

However, as mentioned before, this increase may not reflect an actual increase in number of storms, but might be due to improved reporting. Still, some sources say that there is an increase in this kind of extreme weather events, and that it is due to the ongoing climate change and global warming. [43] At the same time, others say that there is no actual increase in the number of events, but merely an increase in their severity. [44]

Similar to earthquakes and floods, China shows a decrease in the number of people killed in storms over time. From 1980 to 1989, 3 231 people died, corresponding with an average of 87 deaths per storm. Although the absolute number of storm-related deaths increased in the ‘90s, the number of reported events also increased, resulting in a decrease in the average number of deaths per storm to 77.

In the early 21st century, the number of deaths dropped even further, to 3 180 in total and 37 on average per event. On the other hand, as has been demonstrated for the previously discussed natural hazards, the number of people that are affected by storms has increased: from 1.2 million on average per storm in the ‘80s, to 1.4 million in the ‘90s, to as many as 3.3 million people between 2000 and 2009. [2]

Of the top five most deadly storms in China, four were tropical cyclones, and all of them occurred in the eastern and south-eastern coastal provinces. In July 1994, Typhoon Fred killed 1 174 people in Zheijian, Jiangsu and Fujian province, on China’s east coast. The hardest hit was the city of Wenzhou in Zheijian province, where 1000 people died and 2 million others were stranded due to floods. The storm was said to be the region’s worst in 160 years.

Houses, other buildings, roads and power lines were damaged, and many factories were closed. This led to an economic damage of more than 1 billion US$. [2,45,46] In July 2006, typhoon Bilis reached six of China’s south-eastern provinces. The storm lasted for several days and left 820 people dead and 29 million affected.

The heavy rains triggered floods and landslides, which destroyed more than 200 000 houses and severely damaged another 287 000. Almost 3 million people were evacuated. The total economic damage was estimated at 3.3 billion US$, making Bilis the most costly storm in China since 1980. [2,47]

China's storms affect the most people worldwide. In the top ten storms that have affected the most people around the world, eight occurred in China. Remarkably, the storm that affected the highest number of people in China, and in the world, happened in the north of the country, in March 2002. This was not the typical severe rain or wind storm, but a sand storm coming from the Mongolian desert plains in north-west China and Inner Mongolia.

Dust or sand storms are a seasonal event in northern China, but the problem has been growing worse due to deforestation and increased drought in the north. This storm affected more than 100 million people across eight provinces, including 285 000 hectares of arable land. [2,48,49] However, although this storm is listed as the worst in the world since 1980, it did not lead to any deaths, and no estimation has been made of the economic damage that resulted, which raises the question whether number of people affected in itself is a sufficient measure to reflect the impact of a disaster.

A second non-typical storm affected 30 million people in south-west China. This hail storm in April 1989 left 196 000 houses collapsed and 1.74 million houses damaged. 157 people died and 1.19 million hectares of crops were either lost or damaged. The total economic damage was estimated at 400 million US$. [2,50] Most other storms that affected several millions of people were typhoons hitting the east and south-east of China, including the previously described Bilis, which is the number three on the list with a total of 29 million people affected. Most storms that led to big economic losses are typhoons occurring in east and south-east China. [2]

3.3.2 Exposure and vulnerability

As has been discussed for floods, global climate change is influencing the number and severity of storms that occur in China. Higher ocean temperatures can lead to stronger typhoons, but colder temperatures in winter can also result in more blizzards, and increased drought and desertification leads to more frequent and more severe sandstorms. As a result, more areas and thus larger populations are being exposed to storms.

China's high population density in the east and the increasing urbanization are contributing to the vulnerability to storms. For a variety of reasons, people are moving to the cities in the coastal provinces and are being exposed to a different set of environmental hazards, including typhoons. The impact of typhoons on households is most evident in terms of property damage. Houses are frequently damaged, as well as vehicles. In addition, crops, livestock and poultry suffer from typhoons and other storms, being wiped away by strong winds or floodwater.

Loss of lives due to storms is decreasing, which is mainly due to the experience of the affected populations, since many areas are affected on a yearly basis, but also

due to evacuation practices after weather warnings. Households on the coast are more vulnerable, because typhoons gradually lose their strength once they have hit the land. Those living in mountainous areas may receive warnings later than those in plains, and it might take them more time to move to safer places. In general, households with higher income suffer the highest losses, because those with more possessions require more time to bring them to safety. [51]

To mitigate the effects of storms, China has a four-tier colour coded weather warning system, managed by the National Commission for Disaster Reduction. Warnings may lead to evacuation of people from threatened areas and helping boats back to port. Since last year, this system has been further improved in 17 provinces and now includes the sending of text messages from meteorological authorities to residents in case of a red or orange warning, the two highest grades. [52,53]

3.4 Landslides

A landslide can be defined as 'the movement of a mass of rock, debris or earth down a slope'. [25] The term includes a number of events, such as rock falls, slides, or debris flows (mudslides). Landslides are often a secondary disaster to another, primary, event. Events that can lead to a landslide are for example earthquakes, heavy rain, floods and volcanic eruption. Other factors can contribute to the severity of the landslide, including human actions that disturb or change the slope, such as construction work, logging, or building of dams. [54]

3.4.1 Historic events

Since 1980, CRED has reported 65 landslides in China, adding up to an average of 1.9 landslides per year. This makes it the 4th disaster in China in terms of frequency. [1,2] Although landslides do not affect as many people as other disasters, they still account for 3% of all people killed by disasters since 1980, and they affect on average around 43 000 people per event. One landslides that occurred in 2010 in Gansu province, close to the border with Sichuan province, is even among the top 10 deadliest disasters in China, as it killed 1 765 people. [1] This landslide was triggered by torrential rain. Landslides pulled rocks and debris into a river, creating a temporal dam. This led to the building up of water, which resulted in a 3km wide lake.

This lake overflowed, and water, mud and debris slid towards villages downstream of the river. 45 000 people needed to be evacuated form the area, as many houses and other buildings were completely destroyed or severely damaged due to the mudslide. [55] According to experts there were other, indirect factors contributing to the severity of this event. In the area where the landslide occurred, the rock is soft and easily broken, making it more prone to collapse and landslides. In addition, the ground was still vulnerable as an effect of the 2008 Wenchuan earthquake, which badly damaged this region.

Rocks in the mountains had become loose and could easily be broken, and not enough time had passed for them to restore entirely. Lastly, the year before the landslide, the region had experienced extensive drought, which had led to

disintegration of parts of the mountain, making it more susceptible to landslides as a result of rain. [56] Total economic losses due to this landslide added up to 759 million US$. [2]

Landslides have affected mainly the southern provinces, particularly Yunnan, Sichuan, Guizhou and Chongqing. However, landslides have occurred all over China. The most extensive landslide in China affected 2.1 million people. This happened between the 30th of May and the 3rd of June 2010, in Guangxi Autonomous Region. This slide too was due to heavy rains and flooding.

The preceding days of torrential rain had led to the evacuation of almost 80 000 inhabitants, which potentially limited the death toll of this disaster to only 52. However, accompanying floods destroyed more than 117 000 hectares of cropland and 4 226 houses, and caused a total loss of 102.5 million US$. [2,57]

3.4.2 Exposure and vulnerability

Landslides occur in all mountainous areas of China, but the largest impact is suffered by provinces in the south-west. South-western, southern and north-western mountainous regions have the steepest and most rugged slopes, and are therefore most prone to landslides. Landslides most frequently occur during the rainy season, between May and September, showing that heavy rainfall is an important triggering factor. [58,59] As previously described, earthquakes also often trigger landslides, as they increase the instability of the soil.

Settlements close to slopes that are at risk of landslides are especially vulnerable. The potential damage increases in proximity of rivers, because landslides can create temporary dams, causing lakes that risk flooding, even more so when the landslide is triggered by heavy rain. [60]

In addition, a number of human factors contribute to the vulnerability of a community to landslides. Deforestation and construction work along slopes increase the soil instability through erosion. Underground mining can also result in slope instability and consequent landslides due to collapse of the mine. The construction of hydropower stations can indirectly lead to landslides, due to surface excavation. [61]

3.5 Droughts

At first glance, droughts do not seem to be one of the disasters that have a large impact on China. Since 1980, CRED has reported 30 occurrences of drought, a lot less than floods, storms, earthquakes or mass movements. And only three of these have led to deaths, in 1988, 1991 and 2006. However, in total affecting almost 460 million people and causing 36 billion US$ in economic damage, droughts cannot simply be dismissed. [2]

A drought can be defined as ‘an extended period of time characterised by a deficiency in a region’s water supply that is the result of constantly below average precipitation. A drought can lead to losses [in] agriculture, affect inland navigation and hydropower plants, and cause a lack of drinking water and famine’. [25]

3.5.1 Historical events

Most of the droughts reported in CRED's database, occurred in the southern, central and eastern provinces. The drought that led to the highest number of deaths was in the south-east, between February and August 1991. 2000 people died and 5 million were affected. It is reported in CRED's database as world's most deadly drought in the past thirty years. [2] However, since the database still lacks data on other countries that are affected by drought, it might not be an accurate representation.

China's second most deadly drought was in 1988, affecting several provinces in the east of the country. Continuous lack of precipitation resulted in widespread agricultural losses. Some said that one fifth of the arable land was damaged by drought, and in one of the hardest hit provinces even up to half. [62] The severe droughts were combined with high temperatures of close to 40 degrees Celsius, leaving people short of drinking water, and the high temperatures killed many people, especially elderly. [63] The droughts of 1988 caused damage of 942 million US$, affected 49 million people, and cost the life of 1400. [2]

Persistent droughts in 1994 have caused the greatest economic damage: 13.8 billion US$. [2] The most important impact of these droughts was on agricultural production. Although droughts also occurred in the north of China, the middle part was most severely hit. In this region, precipitation was 40-50% less than normal, in some areas even more. Due to insufficient water storage, not only the crop production of 1994, but also that of 1995 was affected. [64]

3.5.2 Exposure and vulnerability

Just like the other extreme weather events that have been discussed here, droughts are becoming more frequent and more severe due to climate change. China's large agricultural sector suffers big losses from droughts and could threaten the national food security, and drought is thus of major concern to the country.

The least vulnerable provinces are those along the south-east coast, as they are abundant in water resources and have a high level of economic development. The provinces most vulnerable to agricultural drought are those in south-west, central and north-east China. This is due to large amounts of total crop planting areas, relatively little rainfall and low levels of economic development.

Agricultural vulnerability also depends on the ability to adapt to local natural conditions. For example, provinces in the west and north have a large proportion of low water consumption crops, because of the low level of precipitation in this region. On the other hand, socioeconomic development can contribute to a region's resilience by improving water management and increasing water conservancy or efficient irrigation practices. [65]

Human factors can also induce or aggravate drought. Discussions have taken place on the effects of the Three Gorges Dam in the Yangtze river, which was constructed for hydropower purposes and to decrease flooding in downstream areas. However, in 2011 when China faced a lack of rainfall, the dam was depriving downstream

areas of water, by storing it for hydropower needs. This resulted in the all but drying up of China's two largest fresh water lakes, dying of fish stock, and shipping on the Yangtze river had to be suspended, which had a significant impact since it is China's most important water transportation route. Eventually water had to be released from the dam in order to relieve the downstream areas. [66]

In addition, deforestation is exposing regions to drought that historically have not had such problems. An example is Yunnan province, which generally has a lot of precipitation during the rainy season, although distribution is uneven. The inequality in amount of rainfall used to be compensated by water management and water conservation in natural forests (through absorption, keeping the ground moist, and trapping water vapour). However, in recent years, natural forests have been replaced by commercial forests that do not have the same capacity. This has resulted in waterlogging in the rainy season, and drought in the dry season. [67]

3.6 Epidemics

Although China has faced a number of devastating epidemics in the early 20th century, few epidemics have occurred in China since 1980. CRED defines an epidemic as 'an unusual increase in the number of cases of an infectious disease, which already exists in the region or population concerned; or the appearance of an infection previously absent from a region'. [25]

3.6.1 Historic events

A cholera outbreak in July 1991 killed 1 074 people, and is therefore the most deadly epidemic China has seen since 1980. This outbreak affected Anhui and Jiangsu provinces in the east, and Sichuan in the south-west of the country. Although not much additional information is available, it is possible that this outbreak was a result of floods. The affected provinces experienced severe flooding during June and July of that year. [2]

Another interesting outbreak was that of severe acute respiratory syndrome (SARS). The first cases were reported in Guangdong province, in the south of China, in November 2002, although at the time they had not been correctly diagnosed. China's initial failure to respond to the outbreak was mostly due to lack of communication. When an investigation report on the unknown disease was completed by the end of January 2003, it was marked top secret, and therefore only available to top provincial health officers. In the meantime, the public remained uninformed in order to maintain social stability.

Due to this lack of awareness, no preventive measures were in place, including for health workers. In Guangdong, nearly half of its 900 SARS cases were health care workers. Finally, in mid-February Guangdong health officials held a press conference about the disease and the WHO was informed. Soon after, the disease had spread to Hong Kong, which turned out to be an important international transit route. Even though fragmented bureaucracy and disruptions in the information flow contributed to the slow and inefficient initial response and prevented international authorities to prepare for the outbreak, once the Chinese government had recognised SARS as a priority, effective measures were put in

place to contain the outbreak, including national and local funds directed to SARS prevention and control. In August 2004 the epidemic had come to an end. [68,69] SARS affected a total of 4978 people in China, and killed 349. [2]

3.6.2 Exposure and vulnerability

Outbreaks of infectious diseases are generally associated with a lack of good sanitary and hygiene practices or the use of contaminated water. The fact that China has not experienced many large-scale outbreaks of communicable diseases in the past few decades reflects the increased access to improved sanitation and water sources. In addition, epidemic prevention is always seen as a priority after disruptions in the systems due to for examples earthquakes, in order to prevent a secondary health disaster. Preventive measures include the provision of safe water and restoration of good sanitation. [24,70]

In the case of SARS, the lack of information made the population more vulnerable. As this was a new disease, the people were not able to protect themselves from infection and therefore a larger population was exposed to the virus.

3.7 Extreme temperature

Although the term *extreme temperature* is not necessarily associated with disaster, it has caused quite some economic damage in China and has affected the lives of numerous people. Extreme temperature manifests itself in China in three types of natural hazards. 'A cold wave can be both a prolonged period of excessively cold weather and the sudden invasion of very cold air over a large area. Along with frost it can cause damage to agriculture, infrastructure, [and] property'. [25]

Extreme winter conditions also occur in China, and can be described as 'damage caused by snow and ice. Winter damage refers to damage to buildings, infrastructure, traffic (esp. navigation) inflicted by snow and ice in form of snow pressure, freezing rain, frozen waterways etc.' [25] On the other hand, there are heat waves, or 'prolonged period[s] of excessively hot and sometimes also humid weather relative to normal climate patterns of a certain region'. [25] Together, these events have affected the lives of more than 81 million people, and caused over 21 billion US$ in economic damage in China. [2]

3.7.1 Historic events

Cold waves and extreme winter conditions mainly affect two large geographical areas in China: Tibet, Xinjiang and Qinghai in the west, and provinces in the south, among others Sichuan, Yunnan, Guizhou, Guanxi and Jiangxi. Two major events occurred recently, during the winter of 2011 and 2008. In January 2011, many provinces in south-west China were affected by a cold wave.

The heavy snow and icy rain made power lines inoperable and many roads were closed, leaving people stranded in their cars. The weather damaged hundreds of kilometres of water pipes, resulting in people facing water shortages. In addition, many houses collapsed or were severely damaged. A total of 233 million people were evacuated. The Ministry of Civil Affairs sent 6 000 tents and 130 000 padded

coats and quilts to the affected areas. [71,72] According to CRED, more than 4 million people were affected by the cold wave, and it cost 281 million US$. [2] In 2008, the results were even more devastating. During the month of January, 1.76 million people were relocated due to collapsed and damaged houses. Railways, highways and airports were paralyzed, leaving many passenger stranded.

Large areas of crops were destroyed by snow and ice. The hardest hit provinces were in southern China. 129 people died, for example due to snow-related accidents. In total some 77 million people were affected by these extreme winter conditions, which cost 21 billion US$. China received humanitarian assistance from several international actors. [2,73,74]

A number of heat waves has also been reported in China. However, they have impacted the country to a lesser extent, with less casualties, less people being affected and less economic damage. [2]

3.7.2 Exposure and vulnerability

Heat waves and cold waves are yet other extreme weather events that China is increasingly exposed to due to climate change. Extremely high temperatures in summer have resulted in excess mortality, especially among the population over 60 years of age, and poses a serious threat to infants. Heat increases mortality and morbidity due to cerebro-cardiovascular and respiratory diseases.

The burden of these diseases is already high in China. Cerebro-cardiovascular diseases represent 45% of all deaths in China, and the associated health care and labour costs are estimated at 2.5 billion US$ every year. This burden is likely to increase as heat waves become more intense and more frequent. However, early warning systems and other protective measures could reduce this burden. [75]

Cold waves can have large economic impacts in China. Crops may be damaged due to the low temperatures, which results in increased prices because of the affected food supplies. In addition, the increased demand for power supply may lead to breakdowns of power-generating systems. Since residential power supply is the priority, industrial consumers are the first to notice the effects of power cuts. [76]

3.8 Wildfires

Wildfire, or ‘uncontrolled burning fire, […] which can cause damage to forestry, agriculture, infrastructure and buildings’,(20) are not common in China. Few grassland and forest fires have been reported, mainly in northern and western China. Most of the damage, human as well as economic, resulted from one event in the north-east in 1987, which killed 191 people, affected more than half a million, and caused economic damage of 110US$. [2]

4 Discussion of technological disasters since 1980

Although China has long been known for the high frequency and death toll of natural disasters, much less information is available on the impact of technological disasters. [77] Even so, CRED provides some data on these events. According to

their database, 865 technological disasters have been reported since 1980, of which the large majority (57.6%) are industrial accidents.

The second most common technological disasters are transport accidents, which account for 28.8%, and the remainder are classified as miscellaneous accidents. In total, 28 092 deaths have been reported due to technological disasters, though this is likely to be an underestimation. [2] Much higher numbers circulate in research and newspapers. For example, CNN [78] reported more than 120 000 deaths in work-related accidents alone between January and November 2003. And BBC [79] mentioned 130 000 deaths due to industrial accidents in 2004. These disparities show a lack of documentation and official reporting.

In China's mining industry, figures on annual deaths in mines were considered state secret for a long time. It was not until the late 1990s that the government acknowledged a yearly death toll of 10 000. Still, analysts considered this number as an underestimation, because mine operators and county officials were reluctant to report accidents in order to avoid retaliation from the government, and because there was a lack of adequate surveys. [80]

However, there does seem to be consensus about the importance of industrial accidents, not only in frequency, but also in death toll. According to the CRED's data, 51% of technological disaster-related deaths are due to industrial accidents. By far the most common accidents are explosions, of which 333 events were reported since 1980, that together resulted in more than 10 000 deaths. [2]

China is ranked as the country with the highest frequency of technological disaster resulting from explosion, fire and poisoning. In fact, the frequency of explosions leading to disaster is ten times as high as for the second country in the ranking list, India. [77]

Important to note is that the lack of long term technological disaster databases in China leads to the failure of tracking and monitoring the human impact of these disasters on the population, and to failure to protect the population from the potential harm. In addition, the scarcity of evidence on epidemiological risk factors and interventions that may reduce the workers' vulnerability in China leads to limited public health policies to protect the population at risk. More research into the health risks of different technological disasters and interacting factors could improve the development of public health policies in this aspect, and the formation of mechanisms to limit or prevent their consequences. [77]

4.1 Industrial accidents

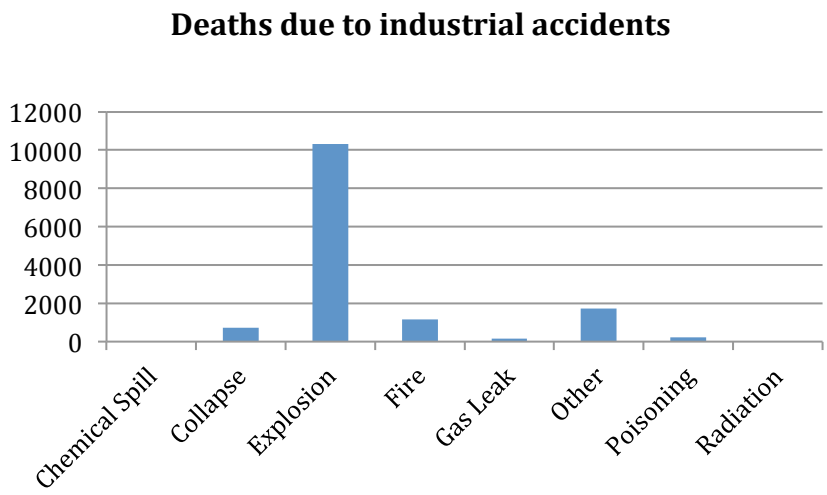
The theory that industrial growth often coincides with increased fatalities in the workplace has quite some anecdotal evidence, including from the United States and the goldmines in South-Africa. One factor that contributes to this increase is the recruitment of unexperienced workers. However, this is not the only factor contributing to the high death rates in China's workplaces.

China has become one of the largest manufacturers in the world, and had an annual industrial growth rate of 12% in the last two decades. But other than

bringing the country economic growth, this industrialization has also cost a great number of lives. Between 1985 and 2002, China reported 200 000 work-related deaths and more than 400 000 injuries. The workplace fatality rate was more than three times as high as in the United States, at 28 deaths per one million workers. Besides the fast increase in labour productivity and workforce, which are generally seen as the main reasons for the increased exposure of Chinese workers to industrial hazards, an important factor is the ignoring of safety regulations by local government officials, employers and workers.

This is due to the strong promotion of economic growth by the government since the 1980s. As enforcement of strict safety regulations might decrease employment and can slow down growth, this promotion provided incentives to impose lax safety regulations. Not until recently did the government start to hold local officials responsible for accidents due to these lax regulations. [81]

Figure 6 Deaths due to industrial accidents sorted by



4.1.1 Mining accidents

China is both the largest consumer and the largest producer of coal in the world. Its mines are also assumed to be the most deadly, reporting 80% of all mining fatalities worldwide in 2003. [81] Mining accidents are the largest subgroup of China's industrial disasters and therefore pose the greatest threat to the population. Shanxi province, which has the largest coal-mining industry in the country (representing around 25% of the total Chinese coal production in 1998-1999), suffers the most accidents. [80]

However, when looking at the number of fatalities per metric ton of coal produced, Shanxi is one of the provinces with the lowest rates. Zheijiang province on the other hand, ranks last in terms of coal production, but has the highest number of fatalities per metric ton of coal produced. This possibly reflects the fact that large mines in areas with high production are operated by the government and have

better technology and safety measures, whereas in other provinces smaller mines are privately owned and have poor technology and a lack of adequate safety in order to keep the costs low. [77] This is in line with findings of other research that shows that accidents in small mines contribute most to the high number of fatalities, rather than the severe accidents that happen in large mines because they are much less frequent. [80]

As was mentioned before, an important factor for the increased vulnerability in small mines, is the unskilled labour force. The underdeveloped provinces tend to be more prone to disaster, because rural populations living in poverty move to find work in illegal industrial operations. Since they have limited options, the migrant workers do not pay attention to safety issues and are willing to work under risky circumstances. [82]

Health hazards posed to mine workers by the accidents include 'injury, wound infections, hypothermia, decompression syndromes, organ damage and death'. [82] A gap exists still in the research on psychosocial effects of the accidents on survivors, although evidence from other countries shows that they are often psychologically traumatised, and that the damage extends to the relatives of the victims. [77] In addition to accidents, however, the mining industry poses other threats to public health.

The use of coal is the leading cause for China's air pollution, and has contributed to cancer being the main cause of death in the country, lung cancer being the most common. In addition, dust and toxic emissions lead to respiratory diseases. In addition to those who die from accidents, 10 000 mine workers die every year due to lung disease as a result of dust. [83] These adverse effects on health, combined with other effects such as pollution, environmental degradation and mining accidents make that the mining industry is also a source of great economic damage. [84]

4.1.2 Other industrial accidents

Another type of industrial disasters that occurs in China, is hazardous chemical accidents, which can be defined as the 'uncontrolled release of a significant amount of toxic, explosive or flammable materials during production, operation, storage, transportation, use and disposal of chemicals, where people, property and/or nearby environment are seriously affected' [85].

A study on the characteristics of this kind of accidents identified differences between accidents in fixed facilities and during transport. For example, accidents in fixed facilities occur more during the day, whereas the average number of chemical accidents in transport was highest between 22.00 and 06.00 hours, and they are usually a result of traffic accidents rather than of the chemical substances transported.

Most of the chemical accidents occur in China's more economically developed region, such as Jiangsu, Shandong and Zheijiang in the east. More than 66% of the accidents are due to common chemical products, including ammonia, sulphuric products, and inflammable gas fuel. 22% of the chemical accidents resulted in

evacuation of nearby residents, which is high compared to the 10% in more developed countries. The reason for this is the proximity of hazardous industrial plants and residential areas. Even if plants were built in scarcely populated areas, due to China's rapid urbanization they have gradually become surrounded by residential areas. This reflects poor urban planning and industrial site layout, which has put a larger part of the population at risk for this kind of accidents and the consequences. For these accidents, explosions are the most common in fixed facilities with 48.4%, but in transportation the main type is release of hazardous chemicals, which made up 79.6% of the cases.

Potential effects that can aggravate the disaster include secondary accidents such as release-fires, serial explosions, collapse and environmental pollution. In terms of health impact, explosions, releases and fires cause the most severe injuries and lead to the most deaths. In the case of China, explosions and releases generally cause more deaths than severe injuries, which in contradicting previous research in other locations. This can be explained by the nature of the accidents. Chemical explosions instantaneously discharge an enormous amount of energy with overpressure wave, thermal radiation and debris impact.

Chemical releases immediately lead to poisoning and suffocating. Therefore, anyone who is in proximity of such an accident will have difficulty to escape and is more likely to die than to suffer severe injury. Timely and proper emergency rescue could limit the severe effects of these accidents, but since most Chinese factories operate with little or no on-site medical care, and accidents often occur in remote places where emergency medical teams cannot provide timely assistance, many seriously injured victims die.

Sometime the number of initial deaths is multiplied several times due to a lack of adequate emergency medical response. The direct causes for hazardous chemical accidents are most often due to human factors, followed by equipment and in about 90% of the cases it is a result of conscious rule-breaking behaviour. Environmental factors and natural hazards are only responsible for a small portion of the accidents. [86]

Besides the coal mining and the manufacturing sector, industrial accidents happen in a number of other energy-related industries, among other the oil chain, natural gas chain, and hydropower. In the oil chain, between 1969 and 1999 one or two severe accidents happened every year, most of which occurred during transportation, but most fatalities occurred in the exploration stages. Accidents in the natural gas industry have been reported since 1989. There are no clear trends in causes or impact of the accidents because of the lack of data, but most of the fatalities occurred in two large accidents in 1993. [80]

Another important source of energy in China is hydropower. China's hydropower industry has a long history, but modern technology was adopted in the first half of the 20th century. It was estimated that in 2000 there were 85 000 dams operating in the country that are being used for hydropower, flood control and irrigation, of which some 22 000 were large dams (46% of the world's large dams). However, according to the Chinese Ministry of Water Resources, more than one third of

those dams were defective and needed to be repaired in the first decade of the 21st century to prevent disaster. [80]

However, in 2011, more than 40 000 dams were still claimed to be at risk for failure. The government has allocated more than 10 billion US$ to a programme to repair and reinforce dams and reservoirs, which aims to make all dams across China safe by 2015. Most of the dams at risk were constructed in the 1950s and 1960s to break the cycle of devastating droughts and floods. At the time, due to limited technology and less developed economy, many dams were constructed from compacted earth and had a lifespan of 50 years, which has already been surpassed. But even though the government is putting pressure on the repair of dams, local governments are reluctant to put that much money and effort into the programme. [87]

4.2 Transport accidents

As in many other countries with motorized transport, has a large burden of transport accidents. According to EM-DAT, most deaths are due to water and road accidents. The database reported 132 road accidents and 74 water accidents since 1980, resulting in 3277 and 3468 deaths, respectively. However, when looking at number of people injured, rail accidents have the largest impact. 22 rail accidents have led to 3469 injured people, which is the largest share of all transport accidents. [2]

Although road traffic accidents and casualties in China have been declining since 2002, they are still a big public health burden. Recently, a more particular event is becoming of major concern: traffic accidents involving school buses. These are of concern because they involve the lives of school-aged children. Between 2007 and 2012, more than 61 school bus accidents happened, in which 373 people were killed and injured.

Most accidents happened in rural areas. There are many reasons for these accidents, but overloaded buses, careless teachers or drivers, illegal buses and poor allocation planning of education with rapid urbanization are the main causes. The most serious accident occurred in December 2012, when 11 were killed and 4 injured. The main causes identified were overloading and speeding, although ground subsidence has also been mentioned as an important factor contributing to the accident. [88]

5 Natural disaster risk reduction

5.1 Policies, strategies and institutions

Disaster reduction activities have been in practice in China for several decades. However, they mainly focus on natural disasters. The lack of policies and strategies to reduce the risk of technological disasters is most likely associated with the underreporting and lack of data on this kind of disasters. So although the existing framework for natural disasters might be used in the response to technological and mass-casualty accidents, there are no specific policies targeting these,

especially when it comes to prevention or mitigation. Therefore, this section on disaster risk reduction only focuses on natural disasters.

Following the founding of the People's Republic of China in 1949, the government set up the Central Commission on Natural Disaster Relief. This commission mainly focused on floods of the big rivers such as the Yellow River and Yangtze River, and promoted self-help and providing work as coping strategies. In the years that followed, China was hit by multiple natural disasters, and the reduction activities expanded throughout the country, but also covered more sectors. For example, the Central Meteorological Administration and the State Seismological Bureau were set up.

In the 1970s, more relevant departments and professional and research institutions were initiated to further enhance the prevention and mitigation activities. Since the 1980s, with the socio-economic progress of the nation, the awareness of the potential damage of natural hazards has increased. In addition, the possibilities of including more advanced technologies gradually modernized the existing systems of disaster reduction. [89]

However, much of the progress has been made since the 1990s. Since 1989, more comprehensive disaster reduction organisations have been established, both at the local and the national level, to expand disaster reduction management and planning, to strengthen education on prevention and mitigation, and to enhance international cooperation. In reaction to the UN resolution on the international decade for natural disaster reduction, the Chinese government established the National Committee for the International Decade for Natural Disaster Reduction in 1989. This was the first inter-ministerial coordinating organisation, aiming to institute a national disaster reduction plan, guidelines, policies and activity plans; to organise and coordinate national and local disaster reduction activities; and to propel international exchange and cooperation. [90]

The fact that the Chinese government recognises disaster reduction as an important way to guarantee development of the national economy and the society, has played an important role in the progress. One of the most pronounced areas of progress, is disaster-related deaths. The number of deaths due to natural disasters has shown a remarkable decrease, especially since the late 20th century. Progress has also been made in construction work, especially in engineering works in areas threatened by floods, including the construction of dikes, reservoirs and irrigation and drainage stations. Monitoring and forecasting systems have been established and are constantly improved. This kind of activities has been strengthened by comprehensive coordination agencies, increased publicity and awareness, and education. [91]

China's current disaster reduction plan is based on the Hyogo Framework for Action [92] and was published in 2006, six years after the implementation of the previous plan, and describes the Action Plan for the period 2006 – 2015. Although since the first plan, the public awareness on the importance of disaster reduction had definitely grown, as well as the response capacity of the country, China was still facing several challenges which called for further development and implementation of the plans. Some of the key challenges identified, include the

spread of social wealth into the high-risk zones due to the continued economic growth and urbanization, and the deterioration of the ecological environment, which leads to an increased frequency and sphere of influence of natural disasters. [93]

5.2 Progress towards Hyogo Framework for Action

The Hyogo Framework for Action (HFA) provides nations with a strategic and systematic approach to reduce vulnerabilities and risks to hazards. Its aim is to substantially reduce disaster losses, in lives as well as in the social, economic and environmental assets of a country or community. [92] China is among the countries that have adopted the framework and are working towards this goal.

5.2.1 Strategic goals

According to a progress report by the government on the implementation of the HFA between 2011 and 2013, China has further integrated natural disaster risk reduction and relief into social and economic development plans. The government has issued several disaster reduction plans, integrated a chapter on disaster prevention and reduction in the 12th National Five-year Plan, and it revised the National Nature Disaster Relief Contingency Plan, which includes strengthened early-warning response and inter-department emergency response linkages.

The progress has not only been at national level. Since 2013, many of China's provinces have established provincial-level disaster reduction committees. Some even have their own coordinating agencies. At the local level, natural disaster response plans have been perfected in towns, villages and communities. In addition, community-based disaster risk reduction has been enhanced, mainly by building demonstration communities that should drive others to establish contingency plans, organize disaster risk inspections, work out their own disaster risk map, etc. [94]

5.2.2 Priorities for action

Although China has been making progress towards the HFA, challenges and constraints remain. The government has been measuring China's progress according to the five priorities for action. Priority one is to 'ensure that disaster risk reduction is a national and local priority with a strong institutional basis for implementation'. At present, China has a relatively complete law regulation system for disaster prevention and reduction. However, this system lacks comprehensive disaster reduction law and regulations, as it is based on the traditional principle of 'one law for one event'.

This hampers the implementation and leads to the inability of eliminating disaster risks. The many laws are redundant and in some cases conflicting, which makes coordination difficult. Another important constraining factor is financial resources. The Chinese government allocates funds specifically for disaster risk reduction and relief, but these funds do not meet the needs and it is difficult to allocate them locally, because integration of disaster reduction and relief are not always integrated into the financial budget of local governments. [94]

Priority for action two, is to 'identify, assess and monitor disaster risks and enhance early warning'. China lags behind in this aspect, because it started very late with disaster risk evaluation. The system is therefore immature and does not yet involve multi-disaster risk management.

Also, lack of a standardized information system makes it difficult to integrate data of various departments into a national platform. However, the natural disaster reporting and monitoring network has continuously developed and has become quite extensive. Early-warning information needs to be expanded especially to rural and remote areas, where at present the information lacks timeliness due to inadequate emergency response communication and information sharing from the local governments. [94]

The third priority involves using 'knowledge, innovation and education to build a culture of safety and resilience at all levels'. In this aspect, China is doing quite well. Disaster prevention and reduction have been incorporated into school-based curriculum according to local conditions, which improves awareness and capability of primary and secondary school students to respond to sudden-onset disasters.

The education department is integrating disaster reduction and prevention into its teaching programme in order to cover all schools and classes. Effort is also put into increasing science and technology in the sector, with several research and development programmes being established. However, limited expenditure by the government restricts improvement, and results in an uneven distribution among different disasters.

For example, much of the research has been done on earthquakes, relating to post-disaster reconstruction, prevention and early-warning systems. For this third priority, differences are also marked at the regional level. Eastern China, due to its more developed economic basis, can put more resources into disaster reduction at the local level, thereby strengthening resilience of the communities, whereas in western provinces resources are scarcer, which results in more uneven development between rural and urban areas. [94]

Priority number four requires reducing underlying risk factors. One of these risk factors is environmental degradation, which can be reduced by incorporating disaster risk reduction into environmental policies and plans such as natural resource management and climate change adaptation. In this aspect China is not doing very well, having a weak basis for environmental emergency response and lacking for example integrated planning for vulnerable areas such as coastal zones. Another key factor is the vulnerability of economic activities.

The Chinese government is tackling this for example by projects for river management, in order to resist floods. In addition, improvements have been made in earthquake-resistant construction. Millions of earthquake-safe houses have been constructed and projects have been initiated to enhance the disaster resistance capacity of primary and middle schools. Infrastructure on the other hand is still in need of further improvement. [94]

The last priority is to 'strengthen disaster preparedness for effective response at all levels'. China has developed great capacity for natural disaster response, and emergency response plan systems have been formed at basically all levels. However, problems remain in quality, feasibility and coverage.

Because the emergency response plan system is characterized by both vertical and horizontal networks, coordination is still a point for improvement, as well as an efficient data-sharing platform. An important element of disaster reduction and enhancement of the emergency response is the emergency drill. Drills are being organized of all sizes and types in accordance with actual conditions, and this helps local departments in their decision making. [94]

Overall China is on the right track. It has a strong institutional basis for natural disaster reduction, which covers all stages of the disaster cycle to a certain extent. However, there is still a lot of room for improvement. One of the major challenges identified here is coordination and information sharing between all levels of government and other institutions involved in disaster reduction.

5.3 Implementation and results

Much of China's achievement in natural disaster risk reduction became visible after the earthquake in Sichuan province in 2008. The efficient response and recovery of the Chinese government has been praised by the international community, and showed especially progress in terms of disaster preparedness, response and reconstruction. A review of the events after the earthquake will show to what extent China has been implementing its policies and plans.

5.3.1 The case of the 2008 Sichuan earthquake

On May 12th, 2008 an earthquake of magnitude 8.0 on the Richter scale struck China. The epicentre was in Wenchuan county, Sichuan province. The impact of the earthquake was huge, and was spread over ten of China's provinces. For weeks after the quake, secondary disasters such as landslides and aftershocks continued to cause devastation and made the relief work complicated. In total, 69 226 people were confirmed to have died, another 17 923 were missing and 374 643 were injured.

Due to the collapse of 5.36 million buildings and 21 million damaged, at least 15 million people were evacuated. [95] CRED has reported the economic loss at 85 billion US$ [2], but the China State Council Information Office [95] estimated the direct losses at even 125.7 billion US$, most of which was due to loss of infrastructure and buildings.

The most severely affected areas covered 130 000km^2 across three provinces (Sichuan, Gansu and Shaanxi), which inhabited almost 20 million people. Most of the affected population were rural residents and relatively underprivileged compared to other parts of China. Regions south-east of where the earthquake hit are much more densely populated, have more resources and are more economically developed than the regions in the north-west, which are relatively isolated and have limited economic and industrial development. [95]

In the initial response, a total of 130 000 Chinese troops were dispatched. In some cases, parachutes were used to access villages that were otherwise inaccessible. In addition, 45 000 nurses and doctors from around the country were mobilized to assist in the relief operations.

Compared to events from the past, the government was faster in providing information and the control over journalists was decreased. Soon after treating many of the direct injuries, the focus shifted to the prevention of epidemics due to disruptions in the water and power supplies and the overcrowd streets and camps. Small medical stations were set up throughout the affected area, and water, portable toilets and facemasks were provided. In addition, booklets were handed out with instructions for the prevention of malaria and waterborne diseases. [70]

On June 8th, less than a month after the earthquake, the government issued the act concerning the Wenchuan earthquake disaster recovery and reconstruction. Throughout June to August, damage research was conducted, temporary housing constructed and recovery plans were being formulated. In September the overall recovery and reconstruction plan was finalized, after which local governments formulated their own plans and residents started the reconstruction of houses. [96]

To provide the financial resources for the recovery, China initiated a new programme, the so-called Partner Support or Twin Assistance programme, in which economically developed provinces or cities provide support to the affected areas on a one-to-one basis. 19 provinces and cities supported 18 heavily affected counties and cities in Sichuan and seriously damaged districts in Gansu and Shaanxi province, by allocating 1% of their annual income to recovery projects for the three years following the earthquake. [95,97]

Collapsed houses were the largest cause for human and property damage during and after the earthquake. In rural areas, some houses were traditionally constructed of wood, and these sustained damage to a lesser extent. However, most of the houses were made of brick, which is one of the reasons for the heavy damage to houses. In urban areas, many houses were built from hollow concrete block or hollow floor panels on brick walls.

The joints between walls and floor panels, reinforced with steel wires, were often still intact, though the floors had collapsed. Many mid-rise housing buildings were also severely damaged, with collapsed joints and damaged brick walls. [96] The ministry of Housing and Urban-Rural Development organized a programme for the provision of one million pre-fabricated houses for temporary settlements of the victims before moving to permanent new houses.

The reconstruction of permanent houses emerged as the most challenging task of the recovery, due to a shortage in funding and limitations of suitable land. Sichuan is one of China's most populated provinces, and in addition geological changes as a result of landslides, mountain movements and changes in watercourses led to a shortage of land for reconstruction of housing. In order to save land, the old small villages where houses were originally scattered around, merged into more compact villages. Before the programme of housing reconstruction started, the

province governments emphasized that the new houses should meet the requirements of the seismic regulations. Because this increased the cost of reconstruction, the government developed several measures to assist those that needed additional financial assistance, including softening of the criteria for loans and small credits, and a provincial guarantee fund. [97]

In addition to residential buildings, many public facilities suffered severe structural damage. These included schools, hospitals, production facilities and infrastructure, which occurred especially in mountainous areas. Especially the reconstruction of schools was important. Most of the schools in Sichuan province needed to be closed due to the extensive damage. [96]

Because the earthquake happened during school hours, an un-proportionally large number of children died, which reinforced safety of primary and middle schools as a key priority of administration at all levels. In 2009, the Ministry of Education started a national programme to upgrade building safety in schools all over the country. In the earthquake-affected areas almost 5000 schools needed to be rebuilt. Local governments usually increased the compulsory building codes with one level and requested that institutions strictly abide by these codes. But attention was not only paid to structural improvement.

In order to make public buildings safer, knowledge, technical skills and management of the risks by local staff should be improved. This was done by providing training through the Twin Assistance programmes. In some cases on-the-job guidance was provided by professionals, in others teachers, doctors and managers received short term training in the donor provinces. This combination of structural recovery and non-structural upgrading resulted in great improvement in the safety of public buildings. [97]

Another point of focus in the recovery after the earthquake was psychosocial support. Experiences have shown that such support is critical for the long-term recovery of people and communities that survive a disaster. A pilot project with a special focus on the most vulnerable groups (elderly, women and children) was set up in six sites in Sichuan province. Almost none of the community health workers had been trained on basic psychosocial crisis intervention or had experience with post-traumatic stress disorder.

Therefore the most important activity of the project was to provide training that covered communicating skills, cognition and treatment of common psychological problems, counselling, post-disaster public health education and self-protection for those working in disaster response. This was the first time that psychosocial support was introduced in China in post-disaster recovery. [97]

In order to avoid long-term dependence on relief programmes and to help recovery and development of the affected areas, the Chinese government had the objective that all affected families should have income sources and the chief labourer of the family should have a secure job. If this would not be achieved, social stability would deteriorate in the affected areas and the government budget would be overloaded by the relief operations. Thus, the Ministry of Human Resources and Social Security subsidized the promotion of employment;

emergency employment services and assistance was restored; and self-employment was encouraged by provision of financial support and favourable business policies. The Twin Assistance programmes also contributed to the restoration of income generating activities, mainly by recruiting local labourers for their reconstruction projects. [97]

As can be concluded from the above, the Chinese government was efficient in its long-term reconstruction planning and did not merely aim for full recovery. Building back better was one of the guiding principles and local authorities were encouraged to view the three year process of reconstruction as an opportunity for development, especially in rural areas. A total of 157 billion US$ was allocated in the plan for restoration work in the affected counties, and local governments were given a predominant role.

Surveys show that there are grounds to describe the recovery process as successful. Most damage was repaired quickly, houses, public facilities and infrastructure were improved, education and healthcare systems continued to function and had resumed normal operations well before the end of the recovery period. Management and coordination of China's government showed a balance between the allocation of resources and devolution to the local level. [98]

Not only did the Wenchuan earthquake lead to further development of national policies on disaster risk reduction, the good practices have also assisted in earthquakes that followed. When a neighbouring province was struck by a strong quake in April 2010, Sichuan province was the first to send relief materials and experienced rescue teams to the affected region. Officials in charge of planning and decision making worked together with officials from Sichuan in the planning of the post-disaster recovery and reconstruction. [97]

Earlier this year, in April 2013, Sichuan province was hit by a 7.0 magnitude quake, which proved to be a test for its emergency system. Although the province's response and coordination had improved since 2008, some problems remained. Landslides again damaged important roads to the hardest hit mountainous areas, and alternative roads were soon blocked by a variety of vehicles. Although traffic control measures were immediately in place, some roads remained congested, resulting in the government's controversial ban on individual volunteers and unauthorised organisations into the area, in order to improve the efficiency of the relief operations.

According to experts, China's response was more rapid and efficient than in 2008, and relief was in place fast and medical care well organized. Since 2010, China has established 22 health emergency teams across the country to respond to different health emergencies. A team from Chengdu, Sichuan's capital, used its fully equipped portable hospital for the first time this year, and three other such teams were sent to the affected areas.

In May 2012, the province had last tested its disaster response system during a drill that simulated a 8.0 magnitude earthquake. More than 10 000 people were involved in the drill, which included search and rescue, triage, evacuation and medical treatment. Although such efforts have strengthened the system, there is

still a need for further improvement. Concerns have been raised about the insufficient air-rescue system, since disruptions in communication and transport after earthquakes remain one of the hardest challenges for relief operations. [99]

So although China has been continuously implementing policies on disaster risk reduction, in recovery as well as in prevention and response capacity, challenges remain. Incorporating risk reduction into the reconstruction process has proven to be effective after the 2008 earthquake, which can be used as an example for future disasters. However, the importance of information sharing about good practices is evident for the further improvement of China's disaster reduction activities.

6 Discussion and conclusions

The aim of this report was to provide an overview of disasters that China faces and their impact, and to relate them with underlying factors that may increase or decrease exposure and vulnerability. The most important constraint to presenting a comprehensive overview was the lack of reliable data on technological disasters. Although it is known that China has a high burden of technological disasters, it was not possible to quantify their impact here and therefore to compare this with the impact of natural disasters.

Due to the much larger amount of information available on natural disasters in China, they have been the focus of this report. However, this does not mean that the risk of technological disasters is less important. On the contrary, studies that have been conducted imply that the impact on human lives currently may be a lot bigger for technological than for natural disasters. Therefore, it is strongly recommended that more research is done on the risk that China faces in terms of technological disasters, and on possible strategies to decrease the population's vulnerability.

For natural disasters, the large diversity and high frequency comes from China's wide variety in geologic, geographic and climatologic features. Regional differences in socioeconomic development and population density mostly account for the variety in terms of impact of the disasters. Overall, provinces in the south and east of the country are most often affected by natural disasters, of which earthquakes, floods and storms are the most frequent and have the largest impact. Trends of the impact over time are also visible.

Since the 1980s, with some exceptions of events such as the 2008 Wenchuan earthquake, the annual number of deaths caused by natural disasters is decreasing. This seems to be a reflection of China's improvement in disaster risk management, which really picked up after the 1980s. While China was making incredible economic progress, the awareness of the consequences of natural disasters for the country's socioeconomic development grew.

It was recognised that disasters affect the potential for growth, both in terms of economy and social development. Mainly preventive and mitigation measures such as construction of dams and dykes for flood control, and increasing building codes for seismic resistance, have helped decrease the number of natural disaster-

related deaths. However, with China's development, exposure to disaster also increased significantly. People's property and its value increased, infrastructure became more extensive, agriculture and industries developed further. All this resulted in increasing economic damage due to natural disasters. For earthquakes, a large proportion of the damage is to buildings.

In urban areas, most buildings are made from concrete and brick: types of structures that are more vulnerable to earthquakes than for example wood and steal. In large cities this vulnerability is increased by the fact that many buildings are high-rise. Still, smaller towns also suffer great amounts of damage, because the building codes are not being implemented to the same extent. For floods and storms on the other hand, concrete and brick houses and other buildings are more resistant. It is the people living in traditional wood-frame houses that are rendered homeless.

At the local level, water disasters have a great impact on agriculture, with large amounts of crops being damaged or completely lost, especially those crops that are sensitive to excessive rain. At the national level, however, economic damage as a result of lost crops is minor, because other areas usually profit from the increase in rainfall that accompanied the disaster. Industries are mainly affected by floods, since China hosts different sectors that are vulnerable to water, such as electronics.

Like economic damage, the number of people affected by natural disasters has also been increasing. This is partially due to the growing population, but also due to increasing urbanization. People are moving to urban areas that are more exposed to floods and storms, because most of the opportunities can be found in cities along the coast, or in the Yangtze river basin.

The combination of less deaths and more people affected reflects the improvements in China's forecasting and early warning system, especially when it comes to hydro-meteorological disasters. This helps the population prepare for impending hazards and eventual evacuation. Impacts on public health are mostly direct, as Chinese disaster relief operations take great care in epidemic prevention, both in case of earthquakes and storms or floods when basic water and sanitary services may be disrupted. Psychosocial damage is getting more and more attention, and was implemented for the first time in a pilot study after the 2008 earthquake in Sichuan province. Since then, reports of other natural disasters have also increasingly mentioned psychosocial disorders as a public health impact.

The fact that natural disasters are increasing in frequency, is mainly due to human factors. Several human activities can induce natural disasters such as floods, droughts or landslides. Examples of these triggering factors in China include deforestation, mining and the construction of hydropower dams. These kinds of activities increase soil instability, which can lead to landslides, and soil erosion, which increases vulnerability to droughts or floods. In addition, combined global human activities are contributing to climate change by the production of greenhouse gasses.

China is a major contributor of these gasses, both due to its large industrial sector and population. However, the most important reason why China's impact on the greenhouse effect is substantial, is that it is the largest consumer of coal, which releases large amounts of greenhouse gasses when burnt. Climate change is leading to more extreme weather events, which China is quite vulnerable to. Floods, droughts, extreme temperature and storms are becoming more frequent and more severe. Policies and strategies for natural disaster risk reduction will have to be adapted in the future in order to cope with the effects of climate change.

Even though it is difficult to obtain reliable and unambiguous data on the risk and impact of technological disasters in China, some general trends were found. Technological disasters have been on the rise, in parallel with China's rapid economic development. The largest share of these disasters are industrial accidents in different sectors, which is in agreement with theories stating that industrial growth coincides with increased fatalities in the workplace. Not only is the number of accidents incredibly large, also the workplace fatality rate is considerably larger than has been reported by other countries.

The most important factor underlying the large impact of industrial accidents, is the lack of safety regulations and their implementation. This is mostly due to the strong focus on economic development and the promotion of growth, which has been at the cost of human life. What makes this matter complicated, is that there are problems at different levels of organization.

For a long time, the government did not hold local officials responsible for industrial accidents that happened under their supervision. In addition, local government officials and employers ignore safety regulations to decrease costs of production, and they often do not report accidents to avoid reprisal by the government. Even workers themselves contribute to the high risk. Many of them are unskilled, which increases their vulnerability and the general risk of accidents. In addition, they do not pay attention to workplace safety, because they have limited options for employment and are therefore willing to work under dangerous circumstances. Improvements should especially be made in the mining sector, which represents the largest share of industrial accidents, and the most mining accident-related deaths worldwide.

In addition to the accidents, the Chinese mining sector poses health threats to a large number of people, not only including workers but also surrounding population. The most important factor that makes China's population vulnerable to health threats from industries, is the proximity of industries to residential areas. This again is a result of rapid and unplanned urbanization.

A vicious cycle seems to be in place around China's technological disasters. Because there is a lack of national policies and regulations, including on information sharing, mystery still surrounds these disasters. This affects the learning and improvement, which could decrease the impact of technological hazards. At the same time, the large-scale ignorance on this topic and its magnitude fails to address the need to develop these policies.

As a result, China's disaster risk reduction to this date does not incorporate technological hazards. National disaster reduction plans and regulations incorporated into the National Five-Year Plans only address natural disasters. And although there is still a need for improvement here, a lot of progress has already been made.

A shift in focus to technological, and especially industrial, disasters could have great potential for reducing morbidity and mortality in China. Therefore, it is strongly recommended that more research is conducted on the risk and impact of technological disasters in China, in order to develop policies and strategies to decrease the population's vulnerability.

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