Disaster Medicine in the 21st Century: Future Hazards, Vulnerabilities, and Risk

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Abbreviations:
BWA = biological warfare agents
HSEE = hazardous substance emergency events

Abstract

The prediction of future disasters drives the priorities, urgencies, and perceived adequacies of disaster management, public policy, and government funding. Disasters always arise from some fundamental dysequilibrium between hazards in the environment and the vulnerabilities of human communities. Understanding the major factors that will tend to produce hazards and vulnerabilities in the future plays a key role in disaster risk assessment.

The factors tending to produce hazards in the 21st Century include population growth, environmental degradation, infectious agents (including biological warfare agents), hazardous materials (industrial chemicals, chemical warfare agents, nuclear materials, and hazardous waste), economic imbalance (usually within countries), and cultural tribalism. The factors tending to generate vulnerabilities to hazardous events include population growth, aging populations, poverty, maldistribution of populations to disaster-prone areas, urbanization, marginalization of populations to informal settlements within urban areas, and structural vulnerability.

An increasing global interconnectedness also will bring hazards and vulnerabilities together in unique ways to produce familiar disasters in unfamiliar forms and unfamiliar disasters in forms not yet imagined. Despite concerns about novel disasters, many of the disasters common today also will be common tomorrow.

The risk of any given disaster is modifiable through its manageability. Effective disaster management has the potential to counter many of the factors tending to produce future hazards and vulnerabilities. Hazard mitigation and vulnerability reduction based on a clear understanding of the complex causal chains that comprise disasters will be critical in the complex world of the 21st Century.

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Introduction

With the new century only in its second year, the world already has witnessed the largest coordinated terrorist attack in modern history in New York City and Washington, DC, which left 3,082 dead or missing and untold thousands seeking emergency care.[1,2] On its heels came the anthrax letter attacks in the eastern US, the largest bioterrorist attack to date, which

resulted in five deaths, and >32,000 persons being placed on prophylactic antibiotics.[3–7] Are these events just random blips in the historical record, or are they portents of catastrophe to come? Can we find a dangerous trend in just two instances? Can we find reassurance in the fact that even larger events did not occur? Can we possibly predict what types of disasters the 21st century will bring?

These questions are not merely academic. Predicting the future drives national and international public policy, government legislation, and the distribution of enormous sums of public money.[8] For example, in requesting $11 billion for biodefense in 2003–2004,[4] the Bush administration has weighed in with its answer to the question of whether bioterrorism will be a future threat.[9] From the perspective of disaster management, predicting the future drives the urgencies of disaster mitigation, the perceived adequacies of disaster preparedness and planning, and the priorities for disaster response.

With so much at stake, how can we possibly begin to know the future? To understand the next century of disasters, we must begin by understanding exactly what is a disaster. According to Gunn, a disaster results from "a vast ecological breakdown in the relations between man and their environment, a serious and sudden event (or slow, as in a drought) on such a scale that the stricken community needs extraordinary efforts to cope with it, often with outside help or international aid".[10] This suggests that disasters are the consequence of some fundamental dysequilibrium between various phenomena or hazards encountered by human populations and the resistance of human populations to these hazards. Whenever the hazard is too great or the resistance too low, then a disaster seems to occur. This trade-off between hazards and vulnerabilities not only defines individual disasters, but presages future risk.[11–15] If we want to embark on the slippery task of disaster risk assessment, then we must have a firm grip on future hazards and vulnerabilities.

Thus, the question about what types of disasters will occur in the 21st Century must be subdivided: What factors will tend to produce the hazards in the 21st Century (natural and anthropogenic)? And equally important, what factors will tend to produce vulnerabilities to hazardous events? Each of these questions must be considered, and their answers ultimately must be integrated into the larger framework of future risk.

Factors Likely to Produce Hazards

The 10 factors that are most likely to produce hazards during this 21st Century include: 1) Population growth; 2) Environmental degradation; 3) Global warming; 4) Deforestation; 5) Infectious diseases; 6) Hazardous materials; 7) Chemical warfare; 8) Nuclear materials; 9) Economic imbalance; and 10) Cultural tribalism. Each of these factors is discussed below.

1. Population Growth

The single most important factor tending to produce hazards in the future is continued world population growth. With the world population increasing at the present rate of 85 million per year (equivalent to the population of Mexico), the total world population is estimated to jump from 5.7 billion in 1995 to 9.3 billion in 2050.[16–18] An expanding world population will cause more environmental stress, consume more resources, create more and larger human settlements, and produce more socioeconomic pressures to coexist.[17,19,20] Accordingly, there will be more natural and anthropogenic disasters of every type, as well as some not yet imagined.

2. Environmental Degradation

Another factor tending to produce hazards in the 21st Century is environmental degradation, which parallels population growth, and is due largely to unchecked human activity. Global warming, one of the most serious forms of environmental degradation, impacts large regions, if not the entire planet.[17,21–24]

3. Global Warming

Global warming has two primary causes: 1) over-production of greenhouse gases due to fossil fuel consumption; and 2) under-absorption of carbon dioxide from a shrinking global carbon sink.[17,22] The net result has been an increase in the global mean surface temperature of 0.2–0.6°C over the last century.[22,24] Furthermore, the warming appears to be accelerating — the 1990s were the warmest decade ever recorded, 1998 was the warmest year ever, and 2001 was the second warmest year ever.[24]

Global warming has been accompanied by increased rainfall in mid to high latitude countries, with many instances of flooding, and increased frequency and intensity of droughts in parts of Asia and Africa.[17,22] In addition, since the 1970s, the El Niño phenomenon has become more frequent, intense, and persistent.[22,25] In 1997–1998, El Niño was associated with at least 22 natural events that resulted in disasters including several floods in South America and droughts and vegetation fires in Indonesia.[21]

By 2100, the mean value for the global surface temperatures is expected to rise another 1.4–5.8°C, not only increasing the risk of extreme weather events, but also raising the mean value for global sea levels by at least 9.88 cm, if not higher.[22,24,26] The areas most vulnerable to inundation from a rising sea level include the Nile delta, the Ganges-Brahmaputra delta in Bangladesh, and many small island states, particularly in Micronesia.[22,23] In these and other low-lying areas, fresh water supplies may be compromised, food production undermined, and disease-causing insect vector populations (e.g., mosquitoes) redistributed to highland areas with weak public health infrastructures and lower levels of herd immunity (e.g., East Africa, Papua New Guinea).[22]

4. Deforestation

Deforestation, another serious form of environmental degradation, is occurring at an alarming pace in many regions of the world.[17,27,28] For example, during the past 30 years, the Brazilian portion of Amazonia (the world's largest tropical forest) has been disappearing at the rate of 0.5% per year.[28] Deforestation not only leads to global warming (through the burning off of forests and the loss of carbon fixation capacity), but also causes soil erosion,

which in turn, is a factor in landslides, floods, and food and fuel scarcity.[17,28]

5. Infectious Diseases

Another flash point for the generation of natural hazards is the interface between the human and the microbial world. Whether considering new, emerging, or re-emerging infectious diseases, the potential exists for the development of infectious disease pandemics.[29–32] During the past 20 years, >30 new disease-causing organisms have been identified, including the HIV, Ebola virus, Hepatitis C, hantavirus, and rotavirus.[30,32] Meanwhile, numerous infectious diseases have re-emerged, including cholera, diphtheria, malaria, plague, and yellow fever, due to environmental factors (e.g., deforestation and the settling of virgin areas), demographic factors (e.g., increased urbanization), and markedly increased international commerce and travel.[29,32]

Perhaps the most chilling example of the devastation that a simple virus can cause is the 1918 global influenza pandemic, which in a matter of a few months, left 20–100 million persons dead (500,000 deaths in the US).[33] The worldwide crude mortality rate in this pandemic was 2.5% (as great as 20% in regions such as Western Samoa).[33] In contrast, World War I left 9.2 million persons dead, World War II, 15.9 million persons dead, and, as of 1997, AIDS had killed 11.7 million worldwide.[33] Although the 1918 flu virus DNA recently was isolated from a victim found buried in the Alaskan permafrost, the mechanism responsible for its increased virulence during that period remains unknown.[33] To be sure, mortality rates would improve with antibiotics against secondary pneumonia, better supportive care, and immunizations. The fact remains that the largest disaster of the 20th Century was caused by an infectious organism of which little is known.

The intentional accumulation of infectious agents as biological warfare agents (BWA) is another factor. In recent years, a number of countries have been implicated either as producing or seeking to produce biological weapons, including Iran, Iraq, Libya, North Korea, Sudan, and Syria.[34,35] Of the many human biological pathogens used in biological weapons, *Variola* and *Yersinia pestis* are the most likely to cause contagious pandemic disasters in civilian populations, since only these spread person-to-person by respiratory droplet.[36,37] Although the deliberate deployment of biological warfare agents as weapons of mass destruction by bioterrorists or a rogue government is feared most widely, repositories of BWAs in non-terrorist nations may lead to similar results. In this respect, it is important to remember that the last known case of smallpox in the world resulted from a laboratory accident in 1978.[38,39] Furthermore, the Ames anthrax strain implicated in the 2001 anthrax letter attacks is suspected of originating from a US BWA research laboratory.[40–42]

6. Hazardous Materials

Hazardous materials are another factor likely to produce human-conceived disasters in the future.[17,43] During the past two decades, the number of disasters caused by industrial chemical spills, gas leaks, industrial explosions, and fires, has increased across the world.[44] Moreover, the 100,000 industrial chemicals in the workplace today are increasing by an estimated 1,000 per year.[45] At least 50,000 chemicals are considered hazardous to humans, with only a handful having antidotes.[46]

In the US, chemicals are produced, consumed, or stored at an estimated 850,000 sites.[47] During the period from 1993–1998, the number of hazardous substance emergency events (HSEE) increased, the number of substances released increased, and the number of deaths due to HSEE increased.[48] In 1998, 79% of the HSEE occurred during production or storage at fixed-facilities (42% in so-called process vessels), while the remainder occurred during transport (82% during ground transport).[49] Although the vast majority of chemical releases are minor (e.g., currently 3.5 chemical releases per day in Texas alone), the potential continues for larger releases to cause disasters.[49,50] In 1984, the largest chemical event in history occurred in Bhopal when an explosion at the Union Carbide India pesticide plant released 27–40 tons of methylisocyanate gas, exposing 250,000–500,000 persons, killing an estimated 2,500–3,000 persons, and leaving many uncounted with chronic pulmonary and neurological disease.[51–54]

The accumulation of hazardous materials also translates into the accumulation of hazardous waste and the potential for slow-onset events.[55,56] There have been many instances of hazardous waste remaining unrecognized in communities until irreversible environmental and human damage has occurred (e.g., Love Canal, USA and Minimata, Japan).[57–61]

7. Chemical Warfare

Chemical warfare agents also remain a continuing problem despite international attempts to control their proliferation. In recent years, a number of countries either have produced or attempted to produce chemical weapons, including Egypt, Iran, Iraq, Libya, North Korea, Sudan, and Syria.[34,35] As a prime example, the Iraqi military deployed nerve agents and mustards against several Iranian villages during 1984–1988.[62,63] During 1995, the Aum Shin Rikyo cult shocked the world, when it released sarin vapor on five Tokyo subway trains, killing 13 persons, sending 5,500 persons to hospitals, and demonstrating that a well-financed, terrorist organization can produce a chemical weapon of mass destruction using common chemical precursors and manufacturing technology.[64–68] The relative ease of production and dissemination of chemical warfare agents makes chemical terrorism the most likely type of terrorism in the future after bombings and multiple shootings.[69–71]

8. Nuclear Materials

During the 21st Century, nuclear material likely will create a number of serious hazards.[72–81] Despite the international attempts to control the proliferation of nuclear weapons, eight nations now have an estimated 31,000 nuclear weapons.[73] Russia and the United States, with 95% of the world's stock, have a combined 1,750 metric tons of weapon-grade uranium and 225 metric tons of weapons-grade plutonium.[73] In recent years, Israel, India, and Pakistan have produced nuclear weapons outside the Nuclear Non-Proliferation Treaty (Israel has an estimated 200, India has 95, and Pakistan has 50), and many are

suspected of developing production capacity.[34] Radioactive material also can be deployed with conventional explosives in so-called "dirty bombs", such as the type tested by Iraq before the Gulf War.[34,72]

Despite concerns about nuclear weapons, nuclear events most likely will occur as a result of nuclear power plant accidents.[77] Although releases of nuclear materials are rare, their impact can be massive, as suggested by the release at Chernobyl in 1986, which led to 30 deaths from acute radiation sickness, evacuations of 100,000 persons, and at least 2,000 delayed cases of childhood thyroid cancer.[82–83] During this new century, as world fossil fuel reserves dwindle (or as global warming worsens), the world will experience an unprecedented increase in demand for nuclear energy, with a consequent increase in the number of nuclear reactors. Although new reactors will be designed to operate more safely, many old reactors will be pressed into continued service.[74] For example, Russia still has in operation three Chernobyl-like, plutonium-producing reactors without containment vessels or emergency core-cooling systems.[76] Two of the 104 commercial power reactors in the US already have been approved by the Nuclear Regulatory Commission for an additional 20 years of service beyond their original 40 year limit.[74,85] Increased nuclear energy also translates into increases in uranium mining, the production of highly enriched uranium, and the re-processing, transportation, and storage of nuclear waste. How fast will this occur? Today, the US and Canada comprise only 5.4% of the world's population, but consume 26.9% of the world's energy. As only one example, if the Chinese public began driving automobiles at the same rate Americans currently do, then the world's fossil fuel reserves would be gone within five years.[86]

The potential for nuclear terrorism also exists, either through the detonation of a nuclear weapon or dirty bomb (acquired or manufactured) or the direct attack on a nuclear power plant.[75,80,81] There is compelling evidence that some terrorist groups have been trying to obtain weapons grade uranium. Since 1993, police in the Czech Republic, Germany, and Turkey each have seized uranium caches in the 0.4–4 kg range, while the International Atomic Energy Agency has reported 175 cases of nuclear trafficking.[80] In recent years, Al-Qaeda agents tried (albeit unsuccessfully) to purchase uranium from South Africa as well as from three central Asian countries.[80,87]

9. Economic Imbalance

Economic imbalance will continue to produce armed conflict within this Century (with resulting complex emergencies).[88] A number of hypotheses have been advanced for this, including economic inequalities within a country (e.g., Bosnia), personal greed of political leaders (e.g., Liberia), failure of the social contract (such as high employment), and extreme poverty or economic stagnation (e.g., Rwanda).[88] The overall incidence of armed conflict and complex emergencies has been increasing since 1950, with most conflict taking place within countries.[89] Armed conflict disproportionately affects the least developed countries—eight of the world's 10 poorest countries recently have suffered or are suffering from armed conflict.[88,90]

10. Cultural Tribalism

Another major factor in producing armed conflict is cultural tribalism, which describes the banding together of a single ethnic or cultural group in order to replace the existing political structure with one based on ethnic or cultural homogeneity.[86,88] Consequences of unchecked tribalism include civil war, terrorism, population displacement, economic dislocation, dissolution of existing political structures, and ultimately, disintegration of the larger nation-state.[86,88] For example, the disintegration of Yugoslavia led to the creation of four independent nations, two nation fragments, and many years of intermittent civil war. Of the 38 armed conflicts in the world in 1999 as reported by the Humanitarian Law Project, cultural tribalism appeares to have been in every one.[91]

Cultural tribalism, in turn, appears to have two major underlying factors. First, with >6,000 cultural groups in the world (i.e., Indonesia has at least 350), most countries are culturally or ethnically heterogenous.[86,92] Only 20 countries truly are homogenous, and relatively few are immune to the pressures of heterogeneity (e.g., Canada has Quebec, Japan has Okinawa, and Spain has its Basque region).[86] Secondly, cultural tribalism gathers its impetus as a direct reaction to globalization.[86] In this respect, globalization describes the spread of transnational economic interests, such as corporations, banks, trade organizations, and the media, in order to open markets, establish free trade, and ultimately earn transnational profits (Table 1). Today, cultural tribalism plays a major role in the current conflict between Islamic fundamentalism and the West.[86,93] Such clashes between parochial and global interests are likely to become more entrenched in future years, making complex emergencies more common and longer lasting than they already are.[86,94]

Factors Tending to Produce Vulnerabilities

Factors that likely will contribute to increasing the vulnerability of the world's population during this century include: 1) Population growth; 2) Aging; 3) Poverty; 4) Population maldistribution; 5) Urbanization; and 6) Structural and functional failures. Each of these factors is discussed below.

1. Population growth

The growing human population not only will generate more hazards, the growth will result in increasing the population's vulnerability to hazardous events.[17] Population growth is exacerbated further by an estimated 80 million unwanted pregnancies in the world every year. Underlying this are the estimated 120 million couples in the developing world still lacking access to adequate contraception.[95]

2. Aging

The world population also is aging. By the year 2050, for the first time in history, the number of older persons (≥60 years of age) is predicted to surpass the number of those who are younger.[96] Concomitantly, the current median value for the age world's population of 26 years is expected to increase to 36 years by 2050.[96] Although today, most developing countries have relatively young population structures (e.g., the median value for the ages of the popu-

Characteristic	Cultural Tribalism	Globalization
Scope	Local, parochial	Global, cosmopolitan
Historical perspective	Antimodern	Modern
Culture	Monocultural	Multicultural
Logic	Mystical	Rational
Problem-solving	Traditional	Experimental
Value system	Absolute	Relative
Political goal	Political totalism	Economic totalism
Freedom cherished	Self determination	Free trade
Political system	Often religious fundamental	Secular

Table 1—Characteristics of cultural tribalism and globalization (after Barber)[86]

lation in Yemen is 15 years versus 41 years in Japan), aging is occurring most rapidly in the developing world, suggesting that these developing countries will have less time to adjust to its consequences.[96] The elderly constitute a unique population at risk in disasters, since they tend to be more susceptible to illness and injury, have chronic medical problems requiring ongoing access to medical care, be homebound, and depend upon the care of others.[97]

3. Poverty

Poverty represents another major area of vulnerability to hazards.[98] An estimated 1 billion people in the world already live on [US]≤$1 per day or less, and half the world's population subsists on ≤$2 per day.[99,100] Some of the poorest nations are so marginalized by a lack of resources that they have fallen into inextricable cycles of poverty and disease, in which one problem begets the other ad infinitum.[101,102] Poverty drives hazard vulnerability at the household level, determining the location and type of housing as well as the resources available for disaster recovery.[103] Accordingly, poor populations and developing countries are more susceptible to natural events, like drought and flooding, and anthropogenic disasters, like complex emergencies and technological disasters.[22,50,92,103–105] Of the approximate 80,000 deaths per year in the world from natural disasters, 95% occurred in "poor" countries.[105,106] For example, Hurricane Mitch in 1998, left 7,500 dead in Honduras, Nicaragua, Guatemala, and El Salvador, led to the evacuation of half the population, and left 75% of Hondurans without clean water. In China in 1998, flooding resulted in 4,000 deaths and the destruction of 7 million homes. In Orissa, India in 1999, a tropical cyclone killed 10,000 and affected 10–15 million. In Mozambique in 2000, flooding caused 500 deaths and created 330,000 homeless persons.[22]

4. Population Maldistribution

Hand-in-hand with overpopulation and poverty is the maldistribution of human populations to disaster-prone areas. Many countries strapped for resources turn a blind eye when human settlements expand near natural hazards, including low lying coastal areas (cyclones, tsunamis), floodplains, seismic areas, landslide-prone areas, and volcanoes.[107–112] With 50% of the world's population already living within 60 km of the sea (and continuing to grow), this trend is unlikely to be reversed without the wholesale intervention of yet more catastrophic disasters.[22] Even developed countries may fail to discourage population growth in disaster prone areas, such as in seismically active California or Japan.

5. Urbanization

Increasing urbanization also will increase the vulnerability to hazardous events. In 2007, the number of urban dwellers in the world is expected to surpass the number of rural dwellers for the first time in history, and sometime between 2010–2020, the urban population in the developing world will surpass its rural population.[113] Meanwhile, the number of megacities (population >10 million) and large urban agglomerations (population >5 million) in the world is expected to increase further.[113] For example, only eight large urban agglomerations existed in the world in 1950, 41 existed in 2000, and 59 are projected for 2015 (with only 11 of these in developed countries).[113] The most rapid rates of urbanization will take place in the currently least urbanized regions, such as Africa and Asia.[113]

From a disaster management perspective, greater urban population density concentrates populations at risk. A classic example is the greater number of casualties that occur when an earthquake strikes an urban area, particularly when buildings are densely concentrated and building occupancies are high.[107] In many developing countries, rapid urbanization outstrips the development of an adequate public health infrastructure, predisposing populations at risk, such as the poor, women, and children, to human-conceived disasters like complex-emergencies.[92]

Poverty and urbanization are interrelated: half of the poor people in the developing world today live in urban slums, which often consist of informal settlements or squatter developments in marginal areas of cities otherwise unsuitable for residential use.[114,115] Known as favelas in Brazil, jhuggie settlements in India, and gecekondu in Turkey, informal settlements share a number of characteristics that predispose their inhabitants to suffer a range of human-conceived and natural events (Table 2).[114,115] From the 1984 Bhopal catastrophe to the recent landslides in Caracas, informal settlements represent a major locus of hazard vulnerability. The marginalization of the urban poor of the developing world into informal settlements will be a growing international concern as poverty and urbanization continue in the 21st Century.

6. Structural/functional vulnerability

Characteristic
Growing population
Overcrowding (increased population density)
Poverty
Increased populations at risk: women, children
Higher baseline incidence of disease
Adjacent to technological hazards (e.g., industrial complexes, solid-waste disposal sites)
Adjacent to natural hazards (e.g., flood plains, landslide-prone areas, earthquake faults)
Homes structurally vulnerable
Inadequate public health infrastructure
Fresh water, food, sanitation, and energy insecurity
Lack of government regulation
Lack of home ownership

Table 2—Characteristics of informal settlements that predispose to disasters[115]

Structural vulnerability to natural forces will continue to affect homes, workplaces, schools, and critical infrastructure, particularly in developing countries.[116,117] Over the past 20 years, natural events have rendered an estimated one billion people homeless, with 14 million losing their homes in a single event, the 1998 floods in China.[116] Whether due to poor design, improper construction techniques, or the use of inferior materials, structural failure is a major determinant of morbidity and mortality from natural events (as well as from spontaneous structural collapse). Foundations give way in floods and landslides, walls topple in cyclones and earthquakes, and roofs cave in under the weight of volcanic ash.[107–112] Structural vulnerability is perpetuated in poor countries by recurrent events, which lead to further under-development.[116] In many countries, nonexistent, ineffective, or corrupt government regulation also may play a role. As a recent example, many of the 43 deaths in the Sultandagi earthquake in Turkey in February 2002 already have been blamed on building practices unchanged since the two earthquakes in 1999 killed 18,000 persons.[118]

The structural and functional vulnerability of critical infrastructure to intentional physical damage by terrorism or armed conflict also will be a future concern. Such infrastructure is involved in ensuring the security of water, food, sanitation, energy, transportation, communication, and information storage for a population. For example, a 1982 study by the US Department of Energy found that if a jet airliner crashed into a nuclear reactor, igniting only 1% of its fuel, the resulting explosion could compromise the integrity of the reactor containment building.[80] The structures that house spent fuel rods at nuclear power plants (with five times more radioactive material than a reactor core) also are vulnerable to deliberate destruction.[80]

Caveats and Conclusions

There is an estimated one disaster-producing event per day somewhere in the world.[90] With an increasing number and scope of hazards and vulnerabilities, this number likely will increase. At the heart of this trend are several interrelated factors tending to produce hazards, including population growth, environmental degradation, infectious agents, hazardous materials, economic dysequilibrium, and cultural tribalism. Equally relevant are a number of interrelated factors tending to produce vulnerabilities including populations that are increasing in magnitude, aging, impoverished, maldistributed to disaster-prone regions, more urbanized, marginalized within urban areas, and poorly sheltered. Underlying all of this is the vast common denominator of an expanding world population chasing limited resources (Table 3).

The increasing interconnectedness of the world also must be considered. Global interconnectedness will bring together hazards and vulnerabilities more rapidly, efficiently, and with greater tangible and intangible consequences. Already, environmental degradation affects large regions, infectious disease is promptly distributed by international travel, civil wars spill across borders, and acts of terrorism impact the entire world. The offspring of this global ecological interdependence will be old disasters in unprecedented forms and new disasters in ways not yet envisioned.

In assessing the risk for future disasters, a major caveat is to remember the critical role played by manageability. Disasters are not *fait accompli*. Disaster risk is dynamic. The likelihood of any given disaster is significantly modifiable through the management of its various component hazards and vulnerabilities.[11–13,117] Using the following equation,

$$\text{Risk} = \frac{\text{Hazard} \times \text{Vulnerability}}{\text{Manageability}} \qquad \textit{Equation 1}$$

it should be apparent that increasing disaster manageability decreases disaster risk — usually through the mitigation of hazards or the reduction of vulnerabilities. In the past, many underdeveloped and under-funded nations have suffered from a sense of fatalism — "There is nothing we can do about it anyway." (e.g., Mekong River flooding), developing nations have remained indifferent until after a disaster strikes — "Other problems are the priority" (e.g., 1999 JiJi earthquake in Taiwan), and developed nations have had a sense of invulnerability — "It can't happen to us!" (e.g., 2001 World Trade Center attack).[119] In the future, the central role of disaster manageability must be stressed at all disaster management, policy-making, and funding levels, from local community agencies to transnational organizations.

A second caveat is that common things are common. The four ancient elements — earth, fire, water, and wind — will continue to figure as the roots of earthquakes, vegetation fires, floods, and tropical cyclones (although in many cases, the reasons will be more complicated and the

Natural hazards	Anthropogenic hazards	Vulnerabilities
Population Growth	Population Growth	Population Growth
Environmental Degradation	Hazardous Materials	Populations Aging
Global Warming	Industrial Chemicals	Poverty
Deforestation	Hazardous Waste	Population Maldistribution
Population Maldistribution	Chemical Warfare Agents	Urbanization
Infectious Agents	Nuclear Materials	Urban Marginalization
New/Emerging Agents	Nuclear Waste	Structural/Functional Vulnerability
Re-emerging Agents	Biological Warfare Agents	
Industrial Chemicals	Economic Imbalance	
	Economic Inequality	
	Personal Greed of Leaders	
	Failure of the Social Contract	
	Poverty	
	Cultural Tribalism	
	Cultural Heterogeneity	
	Reaction Against Globalization	

Table 3—Factors tending to produce future hazards and vulnerabilities associated with disasters in the 21st century

consequences more severe). Whether considering the risk of natural or anthropogenic disasters, it will be vitally important for disaster managers to remain interested in seemingly mundane hazards and vulnerabilities. Even though it will be relevant at times to address the potential for low risk, high impact events (e.g., a bioterrorist-conceived smallpox pandemic), ordinary high risk, high impact problems like the presence of hazardous material in a community or population growth along an earthquake fault, must remain the focus of our ongoing energies.

A corollary to this is that common places also are common. Disasters in the near next century, will continue to plague Asia and Africa, as they did in the late 20th century (due in part to differential population growth).[120–122] For example, Asia has 58% of the total world population on 31% of the surface area, but has suffered 40-50% of all natural disasters and 70% of all disaster-related deaths since 1970 and 90% since 1990.[123] With major hazards (seismic, meteorologic) and major vulnerabilities (more people, more maldistribution), Asia will continue to suffer a disproportionate share of future world disasters.

A final caveat is that disasters are rarely the result of a simple cause, whether the events causing them are natural, human, or mechanical. Disasters always are complicated in origin and consequence. A superficial view holds that the 9-11 terrorist attacks resulted from a worldwide terrorist network against US interests, a string of intelligence and security lapses, the capability of terrorists to commandeer and direct commercial jet liners, and the vulnerability of metropolitan airspace in the New York City and Washington, DC areas. But disasters always unmask hidden problems in a community. Submerged issues invariably surface in some kind of Darwinian challenge to the ecological status quo. Defective chemical processing equipment fails, poorly built buildings fall down, or badly drawn political borders collapse. A deeper examination of 9-11 finds a knot of cause and effect, including millions of impoverished, unemployed, and future-less Arab youth, the strategic dependence of most Western economies on fossil fuel, an Al Quaeda jihad against the Western globalization of the Islamic world, and a generation of failures to broker a meaningful peace in the Middle East. In analyzing the many factors that will tend to promote future disasters, it is important to realize that every disaster is the result of some unique and complex causal chain.

Responsible disaster management in the 21st century translates into responsible disaster mitigation, which in turn will depend on the clearest possible understanding of the root causes of disasters. The identification and characterization of the factors contributing to the production of hazards and vulnerabilities will be central to this process. Risk assessment is the bridge that will take us from the post-disaster improvisation of the past to the pre-disaster preparedness of the future.

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