Unspeakable suffering

– the humanitarian impact of nuclear weapons

Edited by Beatrice Fihn

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Cover photo: Nagasaki bomb victim Sumiteru Taniguchi looks at a photo of himself taken in 1945. His horrific burns have required 17 operations.
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Reaching Critical Will

From the editor

Beatrice Fihn, January 2013

The original idea for producing this publication was formed during the 2012 Preparatory Committee, when more and more countries started to highlight the catastrophic humanitarian consequences that nuclear weapons would cause if ever used. However, it became clear that there was still a lack of evidence-based information regarding the impact of nuclear weapons used in these statements.

In light of this, Reaching Critical Will wanted to gather existing information and research by civil society experts and present it in a clear but still comprehensive way.

This study is aimed both for civil society actors, academics and governments that are interested in approaching weapons negotiations with a humanitarian lens. We hope it will be useful for the upcoming period that hopefully will be shaped by a reframing of the nuclear debate, and for challenging the rhetoric of the nuclear weapon possessors. By highlighting the reality of these weapons and what they would cause if used, this publication demonstrates that a stronger and more concrete commitment to ban and eliminate nuclear weapons must be made now.

Many thanks go out to the authors and researchers of this report: Ray Acheson, John Burroughs, Lloyd J. Dumas, Lily Gardener, Ira Hefland, Barbara R. Johnston, Patricia Lewis, Magnus Løvold, Teresa D. Nelson, M.V. Ramana, Felicity Ruby, Tilman Ruff and Masao Tomonaga.

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In 2012, Dr. Ruff was appointed a Member of the Order of Australia "for service to the promotion of peace as an advocate for the abolition of nuclear weapons, and to public health through the promotion of immunisation programs in the South-East Asia – Pacific region".

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Credit: Defense Image Database/ Tam McDonald

Foreword

Patricia M. Lewis, London, January 2013

By any definition, nuclear weapons would be classed as inhumane. The fact that it has taken decades to discuss the problems they create through a humanitarian framework demonstrates how adept our societies are at forgetting, disguising, and denying the overwhelming and the terrifying.

For far too long, countries that possess them, countries that imagine themselves to be protected by them, and countries that aspire to develop and possess them have created an aura around nuclear weapons. Their immense destructive capacities have served to inspire awe rather than disgust. Their impact on living beings, the environment, and all that we have created, in the short and the long term, has been used to generate a framework in which nuclear weapons are seen as the ultimate guarantee of security. We have built an edifice around a weapon that is too big, too clumsy, and too inhumane to use. We talk about nuclear weapons that are designed to deter not to use. Nuclear weapons—at enormous expense and in large numbers—are supposed to remain in their silos in perpetuity, growling menacingly but never unleashed. Of course it makes no sense.

Nuclear weapons are not magic. Perhaps it seemed that way in 1945 when the harnessing of the energy procured from the breaking of the nucleus of the atom was a new idea, when the promise of this new type of energy was to produce electricity "too cheap to meter". But today, nuclear energy is just one of a mix of energy production measures. Some countries have invested the up-front capital, some have taken on board the risks associated with this type of energy production, and some have decided it is not for them. Similarly for nuclear weapons. The overwhelming majority of countries have decided never to acquire nuclear weapons. Some, through alliance and treaty arrangements, have been assured of the use of nuclear weapons in their defence, should the situation ever arise. Most have sought the opposite, demanding that they never be used against them under any circumstances. Proliferation, despite what the politicians and experts may tell you, is not the norm.

We have been here before. Chemical weapons were the aspirational modern weapon of choice for many countries a century ago. Their inhumane impacts, however, destroyed any credibility of any country that wished to portray itself as civilized. As part of the development of the laws of war and what became known as international humanitarian law, the use of chemical and biological weapons was outlawed in 1925. The possession of these weapons was banned by treaties in 1992 and 1972. Chemical weapons were deemed to be "against the principles of humanity and the dictates of public conscience". The inhumane effects of chemical weapons provide the most sickening reading: vomiting, immediate smothering choking, oedema of the lung possibly death by asphyxiation, blistering, convulsions, loss of bodily control, and long-term nerve damage for survivors. Death through chemical weapons exposure could be seen as a mercy. So too for nuclear weapons.

We should not be proud of the idea that some countries' security could be predicated on the threat of instant vaporization of large numbers of civilians and on enormous numbers subjected to an excruciatingly painful death caused by fires, blasts, and overwhelming prompt nuclear radiation. Following the immediate, devastating impact of a nuclear weapon, first responders and medical personnel, if not killed or incapacitated themselves, would be unable to administer adequate care to survivors. The remaining survivors would be coping with radioactive fallout, contamination, and environment devastation. Depending on other factors, there would be far-reaching regional and global impacts on food and water resources, not to mention the psychological scarring that would pervade and persist through generations. "The living would envy the dead."

Facing nuclear weapons head-on, insisting on honesty, describing what they are rather than what we imagine them to be, would add a new and refreshing dimension to the international discussion. Nuclear weapons are big, clumsy weapons that go bang, do terrible things to living creatures, and leave behind an almighty mess. In that regard they are the same as landmines, cluster munitions, and chemical weapons. We have outlawed those inhumane, military useless weapons because they were finally understood for what they were. It is time to have the same discussion about their nuclear counterparts.

If not here, where? If not us, who? If not now, when?

Impact on health

Credit: Kyodo

The health consequences of nuclear explosions

Dr. Tilman A. Ruff


Credit: Kyodo

Introduction and context: global health on a knife-edge

Nuclear weapons constitute the greatest immediate threat to global survival, health and sustainability. While the total number of nuclear weapons has been reduced from their 1986 peak of 70,000 to 19,000 now, their capacity to produce a global catastrophe jeopardizing the survival of complex life forms is undiminished. Retention of nuclear weapons makes their eventual use inevitable.

A fundamental requirement of responsible public policy is a firm basis in evidence: in this case understanding the physical, biological and ecological consequences of nuclear weapons. The physical realities at the heart of nuclear dangers are that the physical processes inside an atomic weapon and a nuclear reactor are fundamentally similar; that both increase the radioactivity present in the starting materials at least 1 million times; and that fissile materials will be both toxic and weapons-usable for geological periods that make the timeframes of human institutions irrelevant. Therefore a sound policy approach must be based on primary prevention and the inherent dangers of nuclear weapons and fissile materials, and not the changing complexion of political leaders, alliances, governments, or societies. However, evidence of the effects of nuclear detonations has frequently not been collected, or has been covered-up or disregarded by governments in subservience to the myths that nuclear weapons can be used to enhance security and serve legitimate military purposes. The relentless trend of accumulating scientific evidence about the consequences of use of nuclear weapons has been that the stakes are even higher than previously understood; the more we know the worse it looks.

A brief history of medical evidence regarding nuclear weapon effects

The first foreign doctor to arrive in Hiroshima after the nuclear bombing was ICRC delegate Dr Marcel Junod, whose telegrams make chilling reading. On 30 August 1945 he reported:

> *visited Hiroshima 30th conditions appalling. City wiped out 80% all hospitals destroyed or seriously damaged inspected 2 emergency hospitals conditions beyond description. Effect of bomb mysteriously serious. Many victims apparently recovering suddenly suffer fatal relapse due to decomposition of white blood cells and other internal injuries now dying in great numbers. Estimated still over 100,000 wounded in emergency hospitals located surroundings sadly lacking bandaging materials medicines.*[1]

On 5 April 1950, the International Committee of the Red Cross (ICRC) called on all states to take "all steps to reach an agreement on the prohibition of atomic weapons," noting "such arms will not spare hospitals, prisoner of war camps and civilians. Their inevitable consequence is extermination, pure and simple […] Their effects, immediate and lasting, prevent access to the wounded and their treatment." [2]

The nuclear bombings of Hiroshima and Nagasaki demonstrated the devastating multiple and synergistic health effects of nuclear explosions,[3] and the persistent effects of ionising radiation.[4] Nuclear test explosions -conducted by all the nuclear armed states—2060 in all to date—were used principally to evaluate and develop new nuclear weapons, but also to study the effects of nuclear explosions on people, other animals, buildings and other infrastructure. Nuclear test explosions were shown to cause harmful radiation exposures to military and civilian test personnel and downwind communities, and global radioactive fallout was ubiquitous. In the 1950s, prominent physicians like Albert Schweitzer and Benjamin Spock called for an end to nuclear weapons and testing. Rising levels of strontium-90 in deciduous teeth of children worldwide generated concern and protests which helped drive the conclusion in 1963 of the Partial Test Ban Treaty, which banned above ground nuclear test explosions by the USA and USSR. France continued atmospheric nuclear explosions until 1974 and China till 1980.[5]

In 1962, a group of physicians in Boston published a series of articles in the *New England Journal of Medicine* on the medical consequences of a thermonuclear attack on the United States, and the impossibility of any meaningful medical response.[6-10] These reports were the first of their kind by independent physicians. The great majority of reprint requests came from the US Department of Defense. In the 1980s, largely based on official reports on nuclear weapons effects[11-12], a series of reports and books documented in harrowing detail the medical dimensions of nuclear weapons. Some of these were produced by concerned physicians and their associations[13-15], some by national medical associations[16] and national institutes of science and medicine[17-20].

On 22 May 1981, the World Health Assembly (WHA)—the body representing health ministers worldwide which governs the World Health Organization (WHO)—adopted Resolution WHA 34.38, on "The role of physicians and other health workers in the preservation and promotion of peace as the most significant factor for the attainment of health for all". The Resolution requested the WHO Director-General to create an international expert committee to assist WHO's contribution to the prevention of nuclear war. The report of the International Committee of Experts in Medical Sciences and Public Health was considered by the WHA in 1983, and published as *Effects of nuclear war on health and health services* by WHO in 1984.[21] The report concluded that: "It is obvious that no health service in any area of the world would be capable of dealing adequately with the hundreds of thousands of people seriously injured by blast, heat or radiation from even a single 1-megaton bomb […] the only approach to the treatment of the health effects of nuclear explosions is […] the primary prevention of atomic war."

In May 1983 the WHA endorsed the Committee's conclusion that "it is impossible to prepare health services to deal in any systematic way with a catastrophe resulting from nuclear warfare, and that nuclear weapons constitute the greatest immediate threat to the health and welfare of mankind". A second WHO report in 1987 addressed new evidence on radiation effects, firestorms and climatic effects of multiple nuclear detonations and affirmed the earlier conclusions.[22]

Credit: UN Photo/ Mitsuo Matsushige

These reports were important in the world's lead technical health agency for the first time authoritatively documenting the health and environmental consequences of plausible scenarios for use of nuclear weapons. They made a vital contribution to educating the world's medical community, public, and decision-makers about the catastrophic consequences of any use of nuclear weapons, the impossibility of any effective medical response to the effects of even one nuclear weapon exploded on a population centre, and the imperative for primary prevention of nuclear war. They provided an important stimulus to nuclear disarmament and for the end of the Cold War. In 1993 the WHA was the first UN body to request an advisory opinion from the International Court of Justice on the legal status of the threat and use of nuclear weapons. However, requests by the World Health Assembly in 1987 (Resolution WHA 40.24) for WHO to continue investigation of the health effects of nuclear war and for the Director-General to report periodically to the Assembly on progress in this field have not been acted upon.[23]

In more recent years, IPPNW physicians have published a number of further studies[24], including of the health impacts of accidental launch against US cities of 48 100kt warheads[25], 75% of those then on a single Russian Delta-IV submarine, and the effects of a Hiroshima size bomb on a major urban centre such as New York[26,27] or Bombay.[28] In 2007, the City of Hiroshima published a report of a committee of experts examining various scenarios for possible nuclear attack on Hiroshima and recommending how the city should respond to the predicted damage.[29] It did so because under a 2004 national law concerning the protection of the civilian population in situations of armed attack, nuclear attack is listed among the attack scenarios. When the Japanese government failed to respond to Hiroshima's request for a national approach to scenarios, effects and countermeasures, the City undertook its own study. The Committee concluded: "It is not possible to protect civilians from nuclear attack. To protect civilians, there is no measure other than to prevent a nuclear weapons attack from occurring […] To prevent the use of nuclear weapons, there is no other way than to abolish nuclear weapons themselves."

Credit: UN Photo/ Eiichi Matsumoto

One area in which there has been recent attention to the effects of nuclear weapons is in relation to concerns about nuclear terrorism.[30] This has occurred particularly in the years since the terrorist attacks on New York and Washington in 2001, and has been particularly evident in the USA. A recent example is an inter-agency report coordinated by the US Department of Homeland Security which considers the effects and response to a 10-kt nuclear explosion in the centre of Washington DC.[31,32] Such reports typically assume a single isolated event with normal functioning of services and infrastructure outside the immediately affected area.

However in general, there has over the past two decades been a widespread and continuing neglect of research, documentation of updated evidence, policy analysis, discussion, public and professional education, and professional evidence-based advocacy around the medical implications of nuclear weapons and the impotence of response measures other than primary prevention. An editorial in the medical journal *The Lancet* three years ago lamented that the medical and public health attention to the threat posed by nuclear weapons has lapsed badly in relation to its magnitude and urgency, noting that "it is over a decade ago now since *Lancet* published anything remotely relevant to nuclear weapons as a threat to health. Such complacency has been a serious error."[33] However neither *The Lancet*, nor any other high circulation medical journal, has since remedied this error. This is extraordinary and demands attention in the face of what has been authoritatively identified at the highest level as the greatest immediate threat to human health and welfare.

The effects of nuclear weapons

The effects of nuclear weapons are both qualitatively and quantitatively unique. It has been estimated that in World War II, all the explosives utilised by all sides amounted to 3 million tons (3-Mt) of high explosive equivalent, and that all explosives used in all previous wars amount to something over 10-Mt.[21] In comparison, the largest nuclear test explosion ever conducted, on 30 October 1961 at Novaya Semlya was 50-Mt. The largest warheads currently deployed are on Chinese DF-5A land-based missiles, which are up to 5-Mt in size.[34]

Modern warfare has seen a trend for an increasing proportion of casualties to be civilians, and caused indirectly. For example in the First World War, it is estimated that only around 5% of deaths were among civilians. By the Second World War, this was estimated to have increased to 50%. In the Viet Nam War more than 90% of deaths were of civilians, and in most conflicts in recent decades more than 80% of all deaths have been civilian.[35] Beginning in the latter part of the First World War, escalating during the Japanese occupation of China, and increasing extensively in the Second World War, the indiscriminate bombing of civilians—especially through aerial bombardment of cities—and destruction of key life supporting infrastructure became widespread. The latter includes energy and water supplies and distribution, sewage disposal, and transport and communications systems; in effect this tactic is a form of "weapon of mass destruction in slow motion". Such destruction of life-supporting infrastructure disproportionately affects the most vulnerable in a population, including young children, pregnant women, the elderly, and those with chronic illness. Use of nuclear weapons would not only bring the ultimate in indiscriminate devastation in its intensity and extent to the wider biosphere and its life-supporting functions, but would also add unique, indiscriminate, persistent, and trans-generational health harm through ionising radiation.

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Impact on health

Nuclear weapons early direct effects include blast, heat causing burns and igniting massive fires, initial radiation, induced radioactivity, radioactive fallout, and electromagnetic pulse. The extent of the damage varies with a wide variety of factors including the height of detonation, time of day, atmospheric conditions, terrain and infrastructure such as buildings. The extent of blast damage is greatest for airbursts; while in a groundburst the fireball touching the ground sucks up large volumes of earth and debris and instead maximizes radioactive fallout.[22] Any nuclear detonation can be expected to cause profound and largely uncontrollable psychological, social, economic, and political effects, and dangers of nuclear retaliation and escalation which would be global in scope.

Blast

Typically about half the energy released in a nuclear explosion is in a colossal blast wave, travelling at supersonic speed. Injuries are caused directly by the pressure wave (e.g. trauma to lungs and other internal organs, eardrum rupture) but more indirectly, by objects which have been turned into missiles, by people being turned into missiles until they collide with other objects, or collapse of structures. The human body can withstand roughly twice the atmospheric pressure (about 100 kPa), but an overpressure of 35kPa would be associated with winds of 260 km/h, fatally hurling people from buildings or against walls[21,22] (wind speeds over 120 km/h are of hurricane force). Blast would smash vehicles, fuel and other chemical tanks; rupture gas and other pipelines; bring down power cables; cause electrical short-circuits; damage chemical and industrial plants, releasing toxic substances into air, ground, and water; make streets impassable; and cause widespread fires.

Heat

The temperature of a nuclear fireball is in the range of 1 to 100 million °C, and about one third of a nuclear bomb's energy is released as a pulse of heat travelling at the speed of light, causing both direct (flash) burns to any living thing exposed, and flame burns due to fires ignited over a wide area. Anyone who reflexively glanced at the fireball would be at risk of flash blindness and retinal burns. After the Marshall Island nuclear explosions, small animals 555 km away were found with retinal burns. As occurred in Hiroshima and following the intensive aerial bombing during the Second World War of Hamburg, Dresden, and Tokyo, simultaneous ignition of numerous fires over a wide area in cities with their high fuel densities would produce a firestorm, or coalescing superfire. A rising column of hot gases would suck in air, creating hurricane force winds, large areas with ground temperatures of 800 °C, consuming all flammable materials and available oxygen. No one could survive in such a conflagration, and any underground shelters would become crematoria. While the lethal area (the area within which the number of people surviving is equal to the number killed outside the area) for a blast following a 1-Mt bomb—a typical "strategic" nuclear weapon—would be about 100 km2, the lethal area from a superfire caused by the same single bomb would be about 350 km^2 .[22] That is, the number of acute deaths caused by fire would be 3–4 times that caused by blast. Burns are difficult and highly demanding of medical resources and personnel to treat. The United States has about 1760 hospital beds dedicated to specialized care of burn victims; 580 of which are typically unoccupied on any day.[31] A single nuclear explosion could produce tens or hundreds of thousands of burned victims.

Radiation

An initial pulse of neutrons and gamma rays emitted from a nuclear explosion irradiates all living things directly exposed, and neutrons also induce (relatively short-lived) radioactivity in soil and in building and other materials which are not normally radioactive. Nuclear fission (in a nuclear bomb or a nuclear reactor) produces about 300 different radioactive substances, with different decay rates and emissions. Local fallout downwind of a nuclear explosion is greatly increased in a groundburst where the fireball touches the ground and sucks up large amounts of debris, which becomes radioactive. Radioactive products injected into the troposphere (lower atmosphere, where our weather occurs) tend to move with the wind and come down with rain and snow in a band of similar latitude to where the explosion occurred, with hot spots due to deposition by rain and snow. Particularly with larger weapons, radioactive particles reaching the stratosphere (upper atmosphere, beyond the weather) circulate the globe, descending over years as global fallout. The lethal area from superfire following a 1 Mt airburst of about 450km^2 is dwarfed by the area of 5500km2 which under an idealized steady wind of 24km/h, would be blanketed by a cumulative radiation dose of 2 Gray (Gy) from gamma rays alone over about the first day.[14,36] This is roughly comparable to the estimated LD-50 (the dose which kills half of those exposed to it) of 2.5 Gy at the body surface estimated for the survivors of the Hiroshima bomb; and lower than the dose of around 6 Gy which is the LD-50 for acute radiation exposure pertaining under normal conditions in previously healthy people with access to good medical care.[17,22]

Ionising radiation is intensely biologically injurious not because it contains extraordinarily large amounts of energy, but because that energy is packaged and delivered to cells in large packets. The large complex molecular chains, especially of DNA, that define to a considerable extent who we are, and are both our most precious inheritance and the most vital legacy we pass on to our children, are particularly vulnerable to disruption by these large packets of energy. The result is that a dose of ionizing radiation lethal to a human being can contain no more energy than the heat in a sip of hot coffee.

Ionising radiation in doses over 250 milliSievert (mSv) can cause acute radiation sickness and at least over 100 mSv a variety of both reversible and persistent effects in different organs, including an increase in cardiovascular and other chronic, non-cancer diseases. At all doses, without any threshold below which there is no effect, including at doses too low to cause any short-term symptoms, radiation exposure increases the long-term risk of cancer for the rest of the life of those exposed. The most recent published data from studies of Hiroshima and Nagasaki survivors confirm a linear dose-response relationship between radiation dose and cancer risk, with no threshold.[37] The overall increase in risk of solid cancer incidence (occurrence) is about one in 10,000 (and about half that for cancer deaths) for each 1 mSv of additional radiation exposure.[38] The risk for leukemia (blood cancer) is about 10% of this.[38]

Radiation risk however, is not uniform. Infants are about four times as sensitive to radiation cancer-inducing effects as middle-aged adults.[38] A single X-ray to the abdomen of a pregnant woman, involving a radiation dose to the fetus of about 10mSv, has been shown to increase the risk of cancer during childhood in her offspring by 40%.[38,39] Females are overall at close to 40% greater cancer risk for the same dose of radiation as males, and this difference is greatest in young children.[38] Women who are carriers of BRCA1 /2 gene mutations, which put them at high risk of developing breast cancer, have recently been shown to have heightened sensitivity to increased cancer risk from exposure to radiation.[40] Other genetic markers of increased vulnerability to cancer induction from radiation almost certainly exist but largely remain to be identified.

A very consistent and continuing trend in our understanding of radiation health effects has been that the more we know, the worse it looks. Radiation risk estimates and radiation protection standards have always been raised, never lowered. New evidence continues to emerge of radiation health effects beyond those expected. Some recent examples include:

- *The largest study to date of nuclear industry workers, conducted by the International Agency for Research on Cancer and involving over 400,000 workers in 15 countries, produced estimates of cancer risk 2–3 times higher than linear extrapolation from findings in atomic bomb survivors.[41] These findings are not supportive of the reduced harm often assumed to apply for a given radiation dose delivered over a longer rather than a shorter period of time.*
- *German Childhood Cancer Registry data over 24 years demonstrate compelling evidence of an increased risk of childhood leukemia with proximity of residence to a normally-operating nuclear power plant. For children under five years living within 5 km of a nuclear plant, the risk of leukemia is more than doubled and excess risk extends to more than 50 km away.[42] Data from several other countries are consistent with these findings.[43]*
- *Evidence that population exposures across broad regions to low radiation doses from global fallout from nuclear test explosions and the Chernobyl disaster are associated with fewer female babies being born relative to males.[44]*
- *The estimated cancer risk associated with exposure to radon gas was doubled in 2009. Radon is the largest ubiquitous source of environmental radiation exposure and second only to tobacco as a cause of lung cancer.[45,46]*

There has been some confusion and misinterpretation about the genetic consequences of ionizing radiation exposure across generations. It is clear that radiation is a powerful cause of genetic damage. It is also clear that many genetic effects are heritable, that genetic influences on disease occurrence are often complex, interact with environmental factors, and affect multiple body systems. Previously, studies of children born to those exposed to the nuclear bombings in Hiroshima and Nagasaki have not demonstrated an increase in diseases attributable to radiation-induced mutations. However, there is extensive evidence of radiation-induced transmissible mutations in other animals, and there is no reason to believe humans are immune to such harm[38], and there is now emerging evidence indicating an increased risk of leukemia in children whose parents were exposed to the atomic bombings in Japan.

Electromagnetic pulse (EMP)

An intense, brief radiowave pulse produced by a nuclear explosion could cause extensive disruption to electrical equipment. The pulse from an explosion 100 km high would cover an area of 4 million sq km; that from an explosion 350 km high could, for example cover most of North America with a voltage a million times greater than lightning. This energy would be taken up by vast numbers of metallic objects, including electricity cables, telephone lines, railways, and antennae; and transmit this to computers and electronic equipment and circuitry essential to telecommunications, computer systems, transport networks, supplies of water and electricity, and much commerce and trade. Modern industrial, commercial, and urban functioning is highly dependent on electronic and computer equipment.

While an EMP would not be directly hazardous to people, a recent US government commission to assess the EMP threat concluded that an EMP "has the capability to produce widespread and long-lasting disruption and damage to the critical infrastructures;" that "a single EMP attack may seriously degrade or shut down a large part of the electric power grid […] possibility of functional collapse of grids beyond the exposed area" and that if significant parts of the electrical power infrastructure were lost "the consequences are likely to be catastrophic, and many people may ultimately die for lack of the basic elements necessary to sustain life in dense urban and suburban communities."[47]

Modern health care is highly dependent on computers and electrically-operated equipment. In EMP simulation studies, 65% of electronic medical equipment was damaged.[29] Loss of radio and telephone communications would severely hamper any emergency response efforts.

The report from an investigation conducted between 2004-2007 by the US National Academy of Sciences of the vulnerability of the US electricity delivery system to terrorism and how to reduce it was classified in its entirety; most of it being made available publicly only in August 2012. National electricity grids are highly vulnerable to EMP, blast, fires, and other effects of nuclear explosions, and extensive and prolonged outages could be expected.[48]

Combined effects and casualty estimates

A variety of ways have been used to estimate the casualties resulting from nuclear explosions in or over cities, including an overly simplistic focus on blast effects (overpressure model); adding prompt radiation and flash burn casualties; and using the zone of confluent superfires (conflagration model). Some estimates model sheltering provided by buildings and estimate evacuations. In the past decade, most government attention to understanding the effects of nuclear explosions has been in relation to the effects of a single 1–20 kt range nuclear weapon exploded by a non-state "terrorist" organisation. In Hiroshima in 1945 approximately 70% of victims had combined injuries involving combinations of burns, traumatic wounds, and irradiation.[21] Such combinations of multiple injuries and of different types escalate the medical resources required for effective treatment and increase the likelihood of complications and death for the patient.

Remarkably little publicly available work has been undertaken to review and update data on the effects of more widespread use of nuclear weapons by states in light of changing population demographics, changing population distributions and nature of buildings and combustible material in cities in different global regions, and changing nuclear arsenals and targeting strategies. This is true across local, regional, and national governments as well as groupings of states and international organisations. The author is not aware, for example, of any report on any aspect of the effects of nuclear weapons produced by any UN agency since the 1987 WHO report.[22]

On the one hand, more sophisticated and updated methods and estimates of the effects of nuclear explosions would not materially alter the fact that those effects would be so catastrophic that there does not exist anywhere—nationally or internationally—any capacity to ameliorate the consequences in any meaningful way and primary prevention remains the only appropriate response. On the other hand, the remarkable dearth of updated evaluations of nuclear explosions in response to the most acute threat to global health and survival cannot but constitute wilful neglect of the magnitude and implications of those effects, of proper accountability of government, and of the ongoing democratic and humanitarian need for wide public education, understanding, and engagement to drive evidence-based public policy on nuclear weapons. This neglect of evidence and the reality of nuclear weapon effects exacerbates the dangers of their continued possession, deployment, and threats of use. If governments have undertaken studies of the effects of nuclear weapons that have not been made public, they have an obligation to do so.

Illustrative estimates of the effects of a nuclear weapon in the range of the Hiroshima bomb (15-kt) and the Nagasaki bomb (21-kt) include:

- *A 2007 evaluation by a committee of experts convened by the City of Hiroshima estimated that in the first 3–4 months following a 16-kt airburst over the city there would be 66,000 deaths and 205,000 injured persons; and 55,000 deaths, 146,000 injured persons, and up to 402,000 radiation deaths following a surface burst[29] ;*
- *Estimates of casualties (dead and injured) from a 10-kt improvised nuclear device exploded in the central business district of a major US city range from 150,000 in Los Angeles to 500,000 in New York[49], in the latter with a 12.5-kt explosion estimated to cause 52,000 immediate deaths from blast and heat, 10,000 acute radiation deaths, another 200,000 deaths from 24 hour cumulative radiation, and several hundred thousand cases of radiation sickness not fatal in the short-term.[26]*
- *A Hiroshima-size weapon (15-kt) detonated inside a van in Trafalgar Square in London in the middle of a working day has been estimated to cause 115,000 deaths and another 149,000 casualties[50], without taking into account the potentially wider effects of fire conflagration and dispersed radioactive fallout;*
- *In crowded central Mumbai, with population densities exceeding 100,000 people per km², following a 15-kt airburst up to 866,000 acute deaths and up to 2.1 million injured persons are estimated[28]; and*
- *Adapting casualty by distance data from Hiroshima and Nagasaki, Toon and colleagues estimated casualties in the most densely populated regions of various countries following a single 15 kt nuclear explosion.[51] They found up to between 126,000 (UK) and 760,000 (China) deaths, between 214,000 (UK) and 1,379,000 (Egypt) total casualties following an airburst, and up to 111,000 (China) acute radiation fatalities following a groundburst.*

Illustrative estimates of the effects of single larger nuclear explosions include:

- *The 2007 Hiroshima study estimated for a 1-Mt airburst up to 1.16 million acute deaths[29];*
- *A 2011 US Department of Homeland Security report evaluating effects and response needs for a 10-kt groundburst in central Washington, DC estimated—excluding the effects of fires—up to 1.6 million injured persons, including 343,000 people suffering traumatic injuries, 267,000 of them severe, and 201,000 persons suffering acute radiation sickness[31];*
- *A 1.2-Mt nuclear explosion on the Yongbyon nuclear weapons and power facilities in the Democratic People's Republic of Korea would kill more than 500,000 people immediately, with 2 million additional serious casualties[52]; and*
- *Either three 340-kt or a single 1.2-Mt groundburst aimed at Iran's nuclear facilities at Isfahan and Natanz could cause at least 2.6 million immediate deaths, and expose between 10.5 million and more than 35 million people to significant levels of radiation.[53]*

Examples of estimates of the effects of multiple nuclear explosions include:

- *An accidental nuclear attack involving surface explosion of 48 warheads, each 100-kt, carried by 12 of the 16 missiles aboard a single Russian submarine, targeted against key industrial, transportation, financial, and other infrastructure sites in the USA, would cause 6.84 million initial deaths from firestorms alone[25];*
- *262 550-kt warheads targeted on the USA to maximise casualties were estimated to cause up to 100 million immediate deaths from firestorms[54]; and*

Within a distance of 4.7 km in every direction, all living things would die almost immediately-vapourised, crushed, charred, irradiated. 7.5 km in every direction, essentially everyone would be killed or seriously injured. Stretching to out 22.6 km in every direction, everything flammable would ignite, and thousands upon thousands of fires would coalesce into a giant firestorm. Wherever they were, most living thing would die from burns and asphyxiation. Still further out, hundreds of thousands of people would be seriously injured. And everywhere the invisible, silent, lingering danger of radiation would persist.

- *50 15-kt airbursts targeted at urban zones in different countries would produce up to 17.6 million immediate deaths from blast and fires in the case of airbursts, up to 9.3 million similar deaths with groundbursts, and up to 2.6 million short term radiation deaths in the case of groundbursts. The highest number of deaths among the 13 countries evaluated occurred in China, followed by India. The total casualties for China in the case of 50 15-kt airbursts was estimated at 32.2 million; 20.6 million in the case of groundbursts.*[51] *The weapons involved would constitute less than 0.04% of the total explosive yield and less than 0.3% of the number of weapons in the global nuclear arsenal.*

A 5-Mt nuclear explosion

In an attempt to make the unique destructive power of nuclear weapons more comprehensible, the health-related effects of a single 5-Mt nuclear weapon exploded over a major city will be described. Such a weapon is the largest known to be currently deployed. The equivalent amount of TNT high explosive would fill a freight train 2414 km long. Sufficient energy would be released by the explosion of such a bomb to turn 5 million tons of ice to steam. Within a thousandth of a second, conditions akin to the centre of the sun would be produced—100 million °C and 100 million atmospheres of pressure in a fireball, which would rapidly expand to 1.8 km across, releasing a massive burst of radiation, heat, light, and blast.

Within a distance of 4.7 km in every direction, winds of 750 km/h and a blast wave over 140 kPa would crush, collapse, or explode all buildings including those of steel and reinforced concrete and turn the debris into missiles with lethal velocity. Glass and steel would melt; concrete would explode. Wherever they were, all living things would die almost immediately—vapourised, crushed, charred, irradiated.

Out to about 7.5 km in every direction, winds of 460 km/h and blast pressures of 80 kPa would break apart concrete and steel buildings and sweep out their walls, floors, and ceilings. Aluminium would be vapourised. Adults would be hurled over 100m at high speed. Essentially everyone would be killed or seriously injured, including by crush injuries, ruptured lungs, transected spinal cords, severe haemorrhage, and deep burns.

As far as 12.3 km in every direction, winds of 260 km/h and blast pressures of 35 kPa would crush wooden and brick buildings including houses, schools, shops, and many factories. People would be hurled 7m. Asphalt would melt. Windows would be fragmented into more than 4000 projectile glass shards per square meter. Glass and other debris would penetrate people like shrapnel. Many people would have ruptured eardrums. In less than 10 seconds the city would be completely devastated.

Stretching to out 22.6 km in every direction, over an area of 1605 km^2, everything flammable would ignite—wood, paper, clothing, plastics, petrol, and oil from ruptured tanks and cars; all of this would be fuelled further by ruptured gas pipes, downed electricity lines, and leaking chemicals. Within half an hour, thousands upon thousands of fires would coalesce into a giant firestorm 45 km across with temperatures of more than 800°C, sucking in air creating winds of more than 320 km/h, consuming all available oxygen. Wherever they were, every living thing would die from burns and asphyxiation. Shelters would become crematoria.

Still further out, windows would be shattered, buildings damaged, the air filled with broken debris turned into missiles. The streets would be impassable. There would be no ambulances, fire engines or police, no power or communications. People would be trapped under buildings, cars, and fallen debris. Beyond the raging firestorm hundreds of thousands of people would be seriously injured. Crush injuries, fractures, deep lacerations, and internal bleeding would abound. Many would be deaf from ruptured eardrums; many blinded by retinal burns after having glanced reflexively at the fireball. All would be deeply traumatised. Many would lose all will or capacity to function. Everywhere the invisible, silent, lingering danger of radiation would persist. Hundreds of thousands of people would have severe second and third degree burns, requiring the most intensive medical resources and care, but none would be available. Hospitals would have disappeared or be damaged. If they were still standing they would likely have no power or water. Laboratories, operating theatres, sterilisers, ventilators, infusion

The vast majority of injured people would die alone without so much as a human hand or voice to comfort them and without any relief for their agonising pain

pumps, cardiac monitors, and other equipment would either be smashed, burned, or not working from the electromagnetic pulse and loss of power. The few who could reach hospitals or clinics would find that most of the doctors, nurses, and other health professionals would be themselves dead or injured. The few not consumed with their own injuries, losses, or loved ones, who might be able to assist, would quickly run out of any medical supplies they managed to salvage. The vast majority of injured people would die alone without so much as a human hand or voice to comfort them and without any relief for their agonising pain.

Most current nuclear weapons are smaller than a 5-Mt bomb—the most numerous in the US arsenal are between 100- and 455-kt; the most numerous in the Russian arsenal are between 100- and 800-kt.[34] However, multiple smaller nuclear weapons are more efficient at delivering destruction over a wider area, so a single large detonation underestimates the destruction that would be caused by unleashing a large part of the available nuclear arsenals. Recent studies have shown that in nuclear terms "low" yield (Hiroshima size) weapons, if targeted at city centres, can produce 100 times as many fatalities and 100 times as much smoke from fires per kt of explosive yield as high yield weapons.[51]

When the fires ignited by a nuclear explosion had gone out, any survivors, whether injured or not, would likely face a city inhospitable beyond recognition. Safe water, food, shelter, warmth, electricity, fuel, basic goods, assistance, and information would be hard to find. Most of the life-supporting and health-enabling infrastructure and services of modern societies would be severely disrupted. Sanitation breakdown, malnutrition, social disintegration, profound mental trauma, and the ever-present, ongoing, invisible, indiscriminate, and inescapable hazard of radioactivity would combine to fuel increased vulnerability to and spread of endemic and epidemic infectious diseases.

Humanitarian response capacity

Health professional staff, hospitals, and other health care resources are concentrated in urban centres, and would likely be disproportionally affected by a nuclear weapons attack. In Hiroshima, of 300 doctors 270 were reported dead, of 1780 nurses 1654 were dead, and of 140 pharmacists 112 were dead; 42 of 45 hospitals were non-functional.[21] The most recent available US Department of Homeland Security (DHS) assessment of response planning factors following a single 10-kt nuclear groundburst in Washington DC demonstrates the wide gulf that exists between the potential casualties of a single relatively small nuclear explosion and the health care resources available to respond to its aftermath, even in one of the most resource-rich settings (Table).

In Hiroshima, of 300 doctors 270 were reported dead, of 1780 nurses 1654 were dead, and of 140 pharmacists 112 were dead; 42 of 45 hospitals were non-functional[21]

The 2007 City of Hiroshima assessment of another nuclear attack on the city concludes: "no matter how government bodies tried to deal with the situation, the effect would be merely to reduce the casualties on a minute scale."[29] They note that if prior warning could be given to enable people to take shelter indoors, acute

Table: Casualties and health care capacity estimates for a 10-kt ground burst in Washington DC

High consequence scenario 95th percentile

Total injured persons: 1.6 million Persons suffering trauma: 343,000 Moderate-severe trauma: 267,000 Persons suffering acute radiation sickness: 201,000	National capital region: Available hospital beds: 2177 Available ICU beds: 118 Available ventilators: 200 Unoccupied burn beds: 5 Available staff: - Nationwide: Unoccupied burn beds: 580 of 1760 Unoccupied ICU beds: 9400 of 118,000

Note: The effects of fires are not included.

casualties may be reduced, and that in areas far removed from ground zero, evacuation may be effective in reducing casualties. Exposure to early radioactive fallout could be reduced by early sheltering and delayed evacuations following a small number of dispersed nuclear explosions, but the gulf between available medical resources—even if they could be effectively accessed in time—and need, even in the United States following a single small nuclear explosion is salutary.

The Hiroshima Committee of Experts concluded unequivocally: "It is not possible to protect civilians from a nuclear weapons attack. To protect civilians, there is no measure other than to prevent a nuclear weapons attack from occurring, whether it be deliberate or accidental. To prevent the use of nuclear weapons, there is no way other than to abolish nuclear weapons themselves."[29]

The substantial civil defence programmes against nuclear attacks that became widespread in the 1950s were discredited and largely abandoned in the early 1980s because of the work of physicians and scientists demonstrating that these programmes were ineffectual, deceptive and wasteful.[55]

The second WHO report (1987)[22] concluded in relation to management of casualties following a nuclear war: "Obviously the health services of the world could in no way cope with such a situation. In sum, in the event of a nuclear war triage would at best be insignificant, rescue work scarcely other than makeshift […] The great majority of casualties would be left without medical attention of any kind […] When treatment is ineffective, the only solution available to the health professions is prevention. Prevention is obviously the only possibility in case of a nuclear war."

Members of emergency services, other disaster responders, health care professionals, other personnel providing essential services, and the many who may be called to assist in responses to humanitarian emergencies would face unique dangers and difficulties following any nuclear explosion, with widespread and persistent radioactivity severely complicating and hampering access and relief efforts. Many such roles are normally voluntary, and informed consent is required. Disaster response planning should not be based on unrealistic or frankly fictional assumptions about what is possible following nuclear disaster, and responders should not be expected to do the impossible or place themselves at unacceptable danger.

Recent assessments by senior experts of the Red Cross/Red Crescent movement, the world's largest humanitarian organisation, make clear that there are no international plans or capacity for assisting the victims of nuclear explosions[56,57] The 2011 resolution of the Council of Delegates, the highest governing body of the international Red Cross/Crescent movement, "Working towards the elimination of nuclear weapons", in its first operative paragraph: "emphasizes the incalculable human suffering that can be expected to result from any use of nuclear weapons, the lack of adequate humanitarian response capacity and the absolute imperative to prevent such use".[58]

Members of emergency services, other disaster responders, health care professionals, other personnel providing essential services, and the many who may be called to assist in responses to humanitarian emergencies would face unique dangers and difficulties following any nuclear explosion, with widespread and persistent radioactivity severely complicating and hampering access and relief efforts.

Conclusion: a need for evidence-based policy

Evidence of the unacceptable, catastrophic consequences for the health of the human population in case of any use of nuclear weapons is unassailable. Incontrovertible evidence of unacceptable humanitarian effects has been key to the substantial progress made in banning the use of and eliminating other types of indiscriminate, inhumane weapons – biological and chemical weapons, anti-personnel landmines and most recently cluster munitions. Nuclear weapons are far more indiscriminately destructive than any of these.

As noted above, evidence-based advocacy has repeatedly been effective in relation to nuclear weapons. Public and health professional pressure based on evidence of the widespread presence of radioactive fallout including strontium-90 in the deciduous teeth of children in the 1950s and 60s played a major role in the end of atmospheric nuclear tests; in repeatedly extended Soviet nuclear test moratoriums during the 1980s and the eventual near-complete cessation of nuclear test explosions. Serious discussion at the 1985 Geneva and 1986 Reykjavik summits between General Secretary Gorbachev and President Reagan on the complete abolition of their nuclear arsenals over a 15 year timeframe owes much to the work of scientists and physicians in spreading awareness about the catastrophic consequences of use of nuclear weapons and the impossibility of any effective response short of prevention. This was reflected in the joint statement by Gorbachev and Reagan at their 1985 summit that "[a] nuclear war cannot be won and must never be fought."[59] Gorbachev wrote that the 1980s research on nuclear winter had a great influence on him[60] and that without IPPNW's efforts, the abolition of US and Russian intermediate range nuclear missiles and other disarmament initiatives "would probably have been impossible".[61] Physicians played a significant role in New Zealand's nuclear free status; Prime Minister David Lange saying at the 1986 IPPNW World Congress: "You have made medical reality a part of political reality."[62]

In recent decades there has been widespread deliberate denial of the daily existential threat to global health and survival posed by nuclear weapons. In the last generation, no national government or international agency has produced a comprehensive public report on the effects of use of nuclear weapons, addressing squarely the risks posed to human and global security by current arsenals, or their continued modernisation. On the most acute threat to human health identified by the World Health Organisation, we have nothing like the Intergovernmental Panel of Climate Change, whereby the world's foremost scientific expertise is harnessed to update and analyse the evolving evidence and put it before the public and decision-makers. Thus far, only one government—that of Switzerland—has invested, modestly, in examining, validating, and extending the extensively published and peer-reviewed evidence, generated through the initiative and courage of a small number of independent scientists, on the danger of nuclear famine following use of a tiny fraction of the world's nuclear arsenal. This must change. The biggest challenges deserve the greatest attention. Policies on nuclear weapons must be based on the best evidence regarding their actual effects. Our survival depends on it.

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Impact on environment and agriculture

UN Photo/ Nagasaki International Cultural Hall

Credit: Ponds/ Pzaxe

Environmental consequences of a nuclear weapon explosion

Felicity Ruby

Nuclear weapons cause fires, shock waves, and strong winds that disperse radiation in the environment, leading to sickness and death for humans and animals and contamination of water, soil, and air, not once, but for generations.

A number of factors determine the extent and nature of environmental damage caused by a nuclear weapons explosion: design and yield of energy released upon explosions, measured in kilotons or megatons of TNT equivalent; environmental conditions at ground zero, e.g. water catchment, food production area, etc; and weather conditions such as wind that disperse radiation.

What kind of damage is posed to the environment from an atomic blast?

The environmental impacts from the detonation of a nuclear weapon vary depending upon the design of the weapon, the location of ground zero, the type of terrain on which the explosion occurs, the height at which the weapon is detonated, and weather conditions.

The environment is impacted by both radiation (fallout) and non-radiation (fire, blast, shock) effects of nuclear detonation. The altitude of the weapons when detonated will affect the blast, heat, and radiation:

- *Air bursts are below 30km with fission products being scattered over a large area;*
- *Surface bursts are when detonation occurs just above the ground so the fireball burns the land or water with lower radiation than from an air burst except at ground zero;*
- *Subsurface bursts produces cratering below ground or water with nuclear radiation effects occurring but less than in a surface explosion; or*
- *High altitude bursts are detonated over 30 km in the air and disperse energy as heat in greater volume, scattering radiation for hundreds of miles and even into the ionosphere*

hundreds or thousands of kilotons. The fires that weapons of such yields could create serve to make the destruction from incendiary attacks during the WWII on Dresden or Tokyo seem minor. The fire sucking air upwards and creating wind helps to cause explosions of chemicals, petrol stations, domestic waste facilities, and gasses in the affected area, releasing toxins through heat and dispersing them.

In the blast area nothing survives within a certain radius. In Hiroshima a radius of two miles was vaporised; completely destroyed from the blast and the fire. The biggest nuclear device ever exploded—the Tsar Bomba tested at Novaya Zemlya in Russia—generated a blast radius that melted a 35 kilometre square radius. The fireball was 3.5 kilometres. Fireballs from nuclear explosions are up to a million degrees in temperature; sand explodes like popcorn and fires can be set off for many miles.

In Bombing Bombay[1], M.V. Ramana predicts the effects of a hypothetical nuclear explosion over the Indian city:

> *As it expands, the fireball cools down by emitting radiation. Within about 0.1 milliseconds after the explosion, the radius of the fireball is about 15 meters (m) and its temperature, about 300,000 degrees Celsius… In due course, the heated air combined with the products of the explosion and other debris rises to form a mushroom cloud—the symbol of the nuclear age.*

Contained in the cloud of vaporised soil, water, and debris over Hiroshima and Nagasaki were 200 different isotopes; particles irradiated by neutrons were spread far and wide by the blast, fire and wind currents. About 30–40 minutes after the bombing of both Hiroshima and Nagasaki, black sticky radioactive rain fell which was mistaken for oil[2].

Each environment has unique conditions and is inhabited by different creatures and plants. If a nuclear weapon is detonated in the ocean, the radiation, blast, and heat impacts will affect the marine environment. If a weapon is detonated at or near the source or mouth of a river, the ecosystems that will be affected are different

About 30–40 minutes after the bombing of both Hiroshima and Nagasaki, black sticky radioactive rain fell which was mistaken for oil[2]

The yield and design of the bomb, including whether it is a uranium or plutonium device, determines the severity of the blast, and the degree and area size of the environment impacted by the intense blast of heat, light and air pressure, followed by radiation.

The Hiroshima enriched uranium bomb had a yield of 15 kilotons and was detonated at 600 metres above the ground. Over 11.5 square kilometres of wreckage in the city needed to be cleared, which took four years to complete. The Nagasaki bomb was detonated 469 metres above the ground and was a 22 kiloton blast. Many of the 22,000 nuclear weapons in arsenals today have yields of from those that might be felt from a weapon exploded in a desert environment, first from the blast and fireball and secondly from the radiation fall out and contamination.

The nature of the water, soil, rock, or shell at the site of impact will alter the type of particles contaminated and spread, an example being what scientists called the "Bikini snow" that occurred after the US Castle Bravo test of 1954, a 15 megaton explosion on calcinated coral, which caused a white dust of contaminated calcium to fall.[3]
The proximity of the nuclear weapon explosion to surface and ground water resources will leach greater and lesser degrees of radiation to contaminate the water of both local and distant communities.

When a nuclear weapon is exploded at sea fission products present as metallic ions chemically bond to surfaces, which are more difficult to remove when those surfaces are porous—such as with coral or atolls. Ships involved in nuclear testing that experienced fallout were cleaned with continuous water washdown, but only sandblasting or acidic treatment decontaminated the vessels.
While much of the research and writing about nuclear weapons focuses on the intense human suffering, animal genes, tissues, and organs are also impacted by radiation sickness, carcinogenesis, cataract formation, decreased fertility, and genetic mutations. Animals too would be blinded by the light and burned from the rays of the fireball and the radiation sickness. They too would be vulnerable from radioactive fallout to cancer and cell damage given the 2005 report of the National Academies of Science on the risks of ionising radiation[4] found that there is no safe level of exposure to radiation—even low doses can cause cancer and damage cells and cause mutations in future generations of animals. And as with humans, the dangers of radioactive isotopes are most dangerous when they are ingested to be absorbed by muscles, bones, and lungs.

While not a nuclear weapon explosion, the environmental consequences from the Chernobyl disaster reveal how profoundly an entire region might be affected from radiation. The Federation of American Scientists has stated that "contamination from Chernobyl was significantly larger than would have been expected from a nuclear detonation of about 20 kT at ground level, but was comparable in extent to what might result from a 'small' nuclear war in which a dozen or so weapons of nominal yield were exploded at altitudes intended to maximize blast damage."[5]
Twenty-seven years after the accident, restrictions continue on agriculture and fishing in former Soviet states and in many European and Scandinavian countries. Welsh farmers thousands of kilometres away continue to be forced to scan their meat for radioactivity, with some produce unable to be accepted for consumption. Similar impacts on agriculture and fishing may be experienced if a nuclear exchange occurred over food production areas.

The genetic impact on plants and animals around the Three Mile Island area also provide insight into the environmental and impact from radiation exposure. The photographs of Mary Osborn Ouassiai document mutated spiders in that region, damaged deer antlers, and the famous two headed calf born a few years after the accident five miles north west of the plant.[6]

Nuclear testing, conducted to assess the design, yield, and power of both the radioactive and non-radioactive effects, included measuring the ways that weather patterns, particularly wind and rain impacted the environment. The American Public Health Association has noted that if disclosures of the releases had been made public at the times they occurred, implementation of federal protective action guidelines—including removal of soil, destruction of milk and dairy cows, destruction of contaminated human and animal food, and public education about protective measures—would have been required. No public warnings were issued (although the Eastman Kodak corporation was warned in advance of some of the tests, to protect its film stocks).[7]

The environmental consequences of nuclear weapons will be with us for many thousands of future generations regardless of whether another weapon is detonated in war or through an accident.

The past is our clear and present danger

The environmental consequences of nuclear weapons will be with us for many thousands of future generations regardless of whether another weapon is detonated in war or through an accident.

Let the Facts Speak[8] is a chronology documenting known nuclear accidents and incidents from the beginnings of the Manhattan Project in the 1940s to Fukushima and beyond. The compilation is an attempt to gather all publicly available information to ensure that the contamination arising from the nuclear fuel chain is never forgotten. However, given the highly secretive nature of the research, development, testing and deployment of nuclear weapons, we may never know the true environmental legacy of nuclear weapons to date.

We can list the 2,053 times and places that white flashes sent shadows fleeting across deserts or mushroom clouds boiled into the stratosphere or melted sand into glass deep underground through nuclear testing. Because of state secrecy in the name of security we do not know about incidences that occurred before or after those tests, the many mishaps, crashes, spills, dumps or burials of mutagenic and carcinogenic substances such as plutonium, uranium, strontium, carbon-14, radioactive iodine and caesium, all generated in nuclear weapons programmes.
The unsolved problem of nuclear waste is an enduring argument for suspending the industry, auditing the nature and location of stockpiles, and urgently devising contingency plans for shielding people, food production areas, and water sources from the highly toxic and genetically harmful problem the nuclear age has generated.

The radioactive waste created in the manufacture of one average nuclear bomb includes 2,000 tons of uranium mining waste, four tons of depleted uranium, and 50 cubic metre of 'low-level' waste.[9] In the US alone, according to the Department of Energy's Paths to Closure report, the clean-up following nuclear weapons production and testing is projected to cost more than US$300 billion through the year 2070. The clean-up process will generate more radioactive waste; anything that touches or contains radiation becomes toxic, and the sites will require monitoring and stewardship into the far future.[10] And of course, there still is no solution to the problem of nuclear waste. Creating nuclear waste is the radioactive equivalent of building a house without building a toilet.

Conclusion

The nuclear age is 68 years old. We do not yet know the long-term consequences for agriculture, animals, and ecosystems from the fallout from nuclear testing already endured. The long-term damage through the production and deployment of nuclear weapons also poses a threat but the existence of nuclear weapons threatens environmental catastrophe and long term contamination. Nuclear disarmament is the first step to wrenching the hands of the Doomsday Clock away from midnight; however, the plutonium stockpiles in existence already ensure that humanity will never be able to turn back the clock on the nuclear age and the culpable release of radiation it has inflicted on thousands of future generations.
While this chapter has briefly sketched the range of variables determining the impact on the environment from a future possible detonation scenario, the toxic legacy arising from the history of nuclear weapons production is relevant because it too poses a clear and present danger to the environment. Given the long-lasting nature of nuclear materials, 250,000 years in the case of plutonium, notions of future dangers as distinct from past dangers are relatively irrelevant if not moot.

Threats arise from an attack on waste facilities and radioactive materials becoming bioavailable through leaking into the water, air or soil. This is not a minimal risk as independent estimates of the global stockpile are 1,440 tons of highly enriched uranium and 500 tons of separated plutonium in existence in a large number of locations, many secret.

All nuclear dangers are enhanced by the shroud of secrecy routinely placed over nuclear programmes. Whether it is due to commercial or national security reasons, the work force and decision-making processes at most stages in the nuclear chain are muted and enjoy weak regulation, exemption from freedom of information and very limited public scrutiny.

If we are to protect the environment from nuclear dangers, then transparency and accountability on the part of nuclear weapon states about the location and severity of contamination at sites impacted by nuclear weapons will be a necessary stage in the nuclear disarmament process.

Notes:

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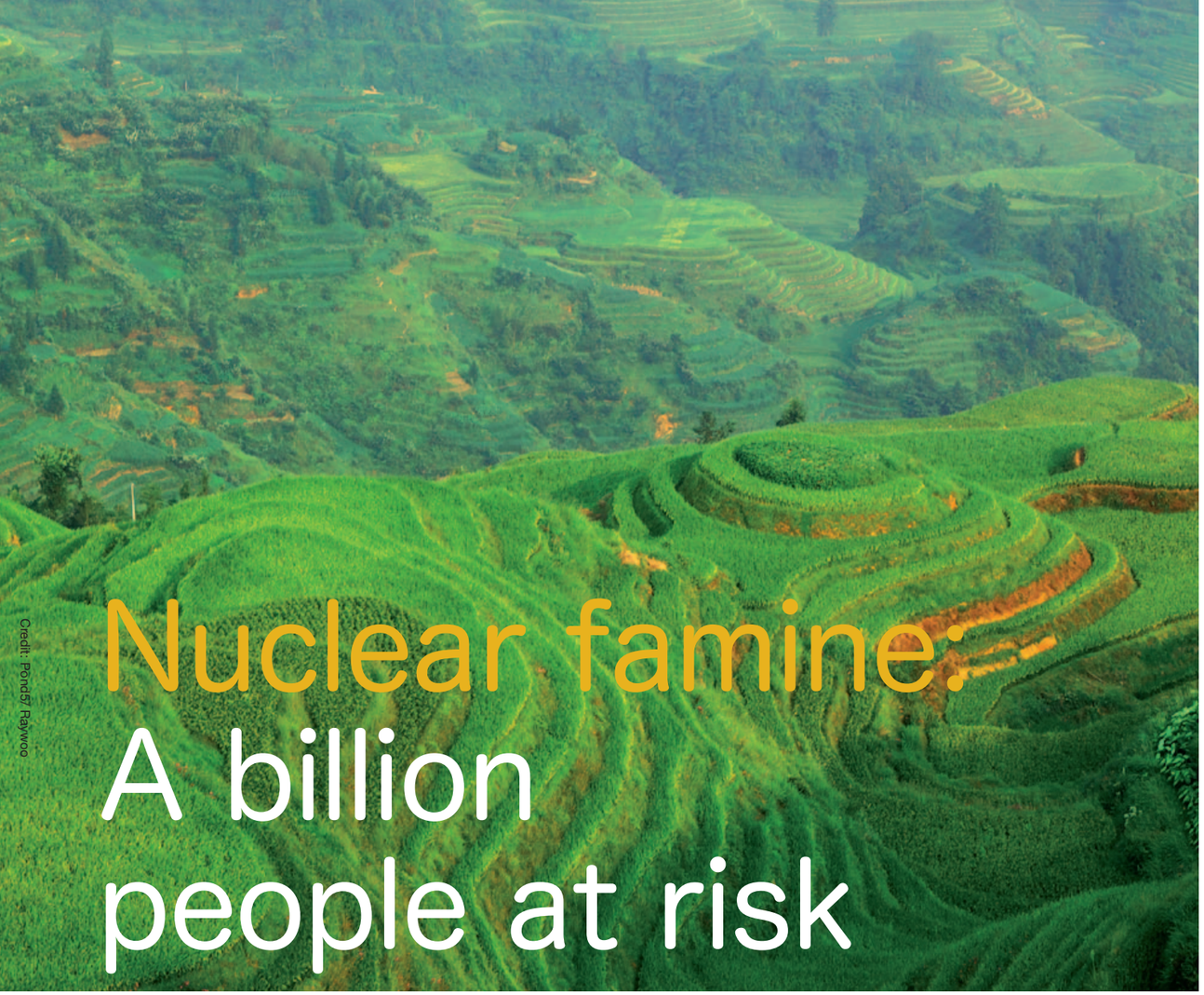
Credit: Pond5/ Sergey Nivens



Credit: Pond5/ Raywoo

Nuclear famine: A billion people at risk

Dr. Ira Helfand

Introduction

Over the last several years, a number of studies have shown that a limited, regional nuclear war between India and Pakistan would cause significant climate disruption worldwide. Two studies published this year examine the impact on agricultural output that would result from this climate disruption. In the US, corn production would decline by an average of 10% for an entire decade, with the most severe decline, about 20% in year 5. There would be a similar decline in soybean production, with, again, the most severe loss, about 20%, in year 5.

A second study found a significant decline in Chinese middle season rice production. During the first 4 years, rice production would decline by an average of 21%; over the next 6 years the decline would average 10%. The decline in available food would be exacerbated by increases in food prices, which would make food inaccessible to hundreds of millions of the worlds poorest. Even if agricultural markets continued to function normally, 215 million people would be added to the rolls of the malnourished over the course of a decade.

However, markets would not function normally. Significant, sustained agricultural shortfalls over an extended period would almost certainly lead to panic and hoarding on an international scale as food exporting nations suspended exports in order to assure adequate food supplies for their own populations. This turmoil in the agricultural markets would further reduce accessible food. The 925 million people in the world who are chronically malnourished have a baseline consumption of 1,750 calories or less per day.

Even a 10% decline in their food consumption would put this entire group at risk. In addition, the anticipated suspension of exports from grain growing countries would threaten the food supplies of several hundred million additional people who have adequate nutrition today, but who live in countries that are highly dependent on food imports. The number of people threatened by nuclear-war induced famine would be well over one billion. These studies demonstrate the need for additional research and underscore the urgent need to move with all possible speed to the negotiation of a nuclear weapons convention that will eliminate the danger of nuclear war.

Background

In the 1980s, a number of scientific studies demonstrated that a large-scale nuclear war between the United States and the Soviet Union would cause "Nuclear Winter", a profound worldwide climate disruption with significant decreases in precipitation and average surface temperature. A US National Academy of Sciences study on the medical consequences of nuclear war concluded that, in the aftermath of such a war, "the primary mechanisms for human fatalities would likely not be from blast effects, not from thermal radiation burns, and not from ionizing radiation, but, rather, from mass starvation."[1] While the direct mortality attributed to a "large-scale nuclear war" was estimated at several hundred million people, the subsequent food and health crisis was expected to result in "the loss of one to four billion lives."

In 2007, a study by Robock et al demonstrated that even a very "limited" regional nuclear war, involving only 100 Hiroshima-sized bombs, or less than 0.5% of the world's nuclear arsenal, would also produce global climate disruption, although the impact on temperature and precipitation would be less profound.[2] At that time, there were no data on the effect that the predicted climate disruption would have on agricultural production. The historical experience following cooling events caused by volcanic eruptions, most notably the Tambora eruption in 1815, suggested that there might be a very significant impact on food production and human nutrition. A 2007 report by the International Physicians for the Prevention of Nuclear War and its US affiliate, Physicians for Social Responsibility, suggested that up to one billion people might starve if a limited nuclear war led to even a 10% decline in their food consumption.[3] This report is an initial attempt to quantify the impact of a limited nuclear war on agricultural production and the subsequent effects on global food prices and food supply, and on human nutrition.

Climate disruption from a "limited" regional nuclear war

A 2007 study by Toon et al[4] considered the consequences of a possible nuclear war between India and Pakistan and showed that such a conflict would loft up to 6.6 Tg (6.6 teragrams or 6.6 million metric tons) of black carbon aerosol particles into the upper troposphere. Robock et al then calculated the effect that this injection of soot would have on global climate assuming a war in South Asia occurring in mid May.

Their study used a state of the art general circulation climate model, ModelE from the NASA Goddard Institute for Space Studies, and employed a conservative figure of only 5 Tg of black carbon particles. They found that, "A global average surface cooling of -1.25°C persists for years, and after a decade the cooling is still -0.50°C. The temperature changes are largest over land. A cooling of several degrees occurs over large areas of North America and Eurasia, including most of the grain-growing regions." In addition the study found significant declines in global precipitation with marked decreases in rainfall in the most important temperate grain growing regions of North America and Eurasia, and a large reduction in the Asian summer monsoon.[5]

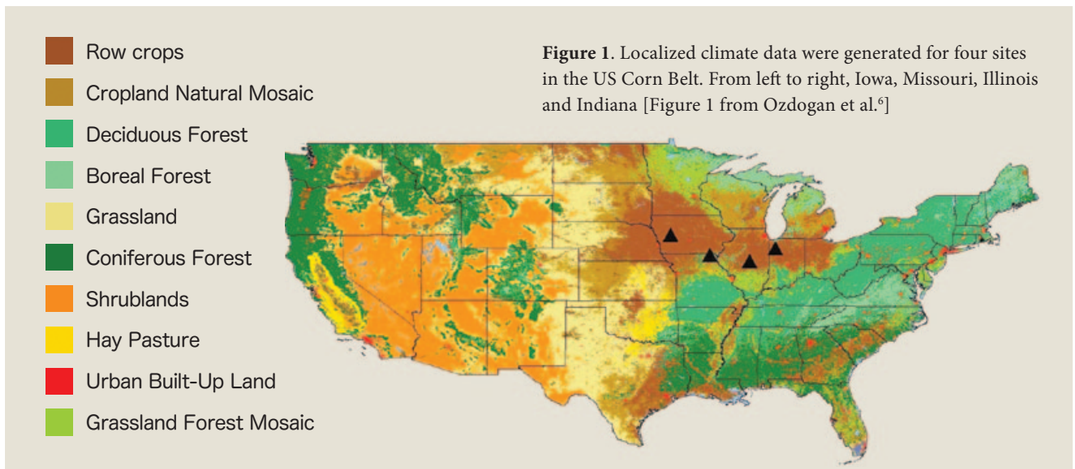


Figure 1. Localized climate data were generated for four sites in the US Corn Belt. From left to right, Iowa, Missouri, Illinois and Indiana [Figure 1 from Ozdogan et al.[6]]

Credit: UN Photo

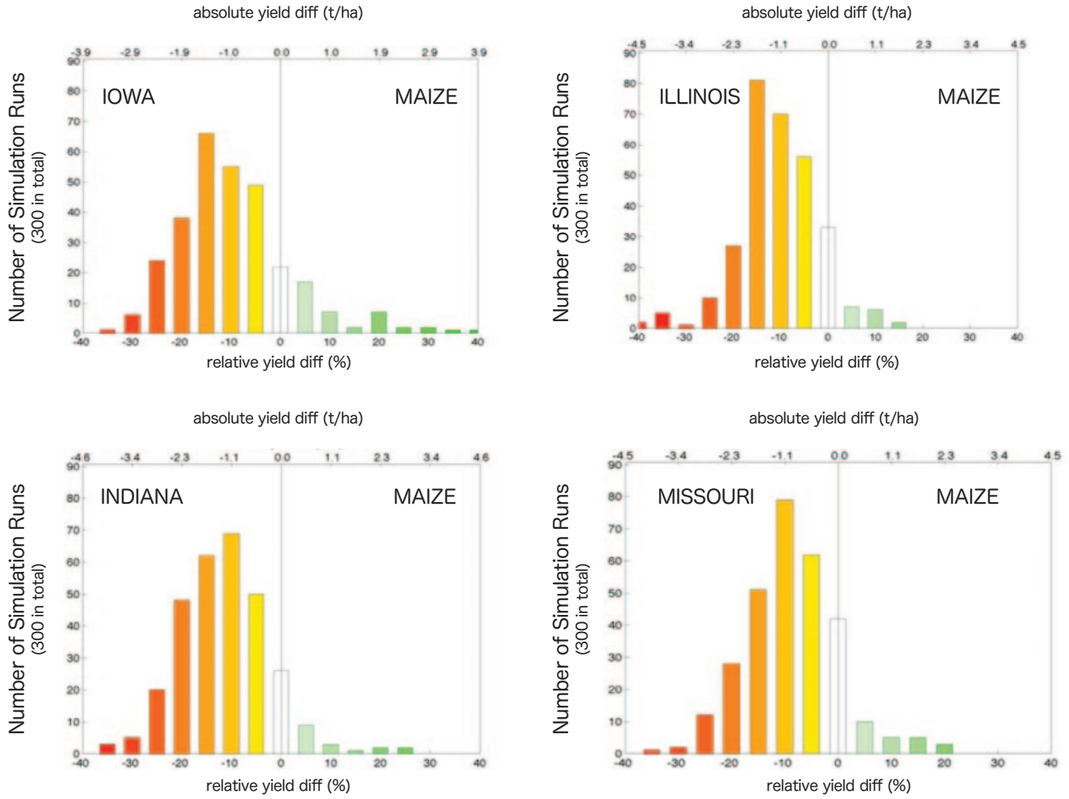


Figure 2. Declines in US com (maize) production. To generate an estimate of the probable change in crop yield, computer simulations were run to obtain 300 different baseline crop yield levels using random selection of annual climate data over the past 30 years. The x axis shows the percent change in crop yield from the estimated baseline; the y axis shows the number of simulations that yielded a change of that size[Figure 7 from Ozdogan et al.[6]]

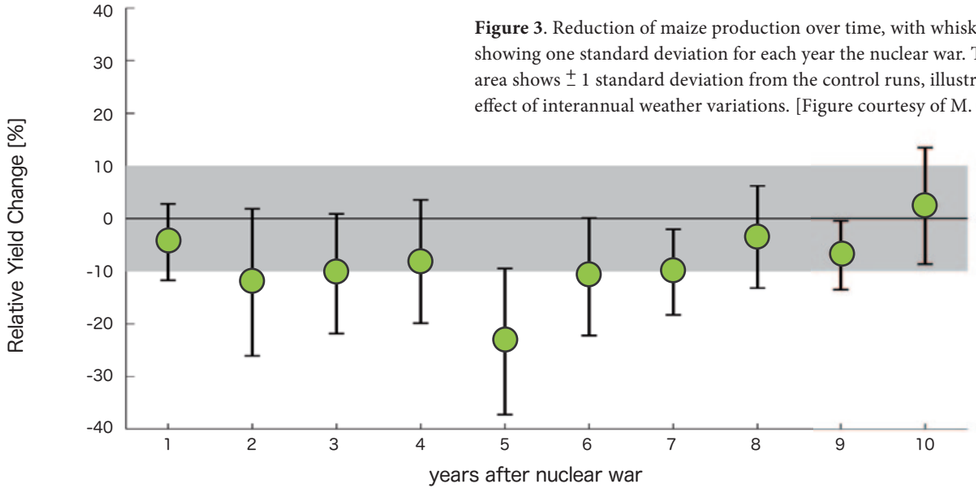


Figure 3. Reduction of maize production over time, with whiskers showing one standard deviation for each year the nuclear war. The gray area shows ± 1 standard deviation from the control runs, illustrating the effect of interannual weather variations. [Figure courtesy of M. Ozdogan.]

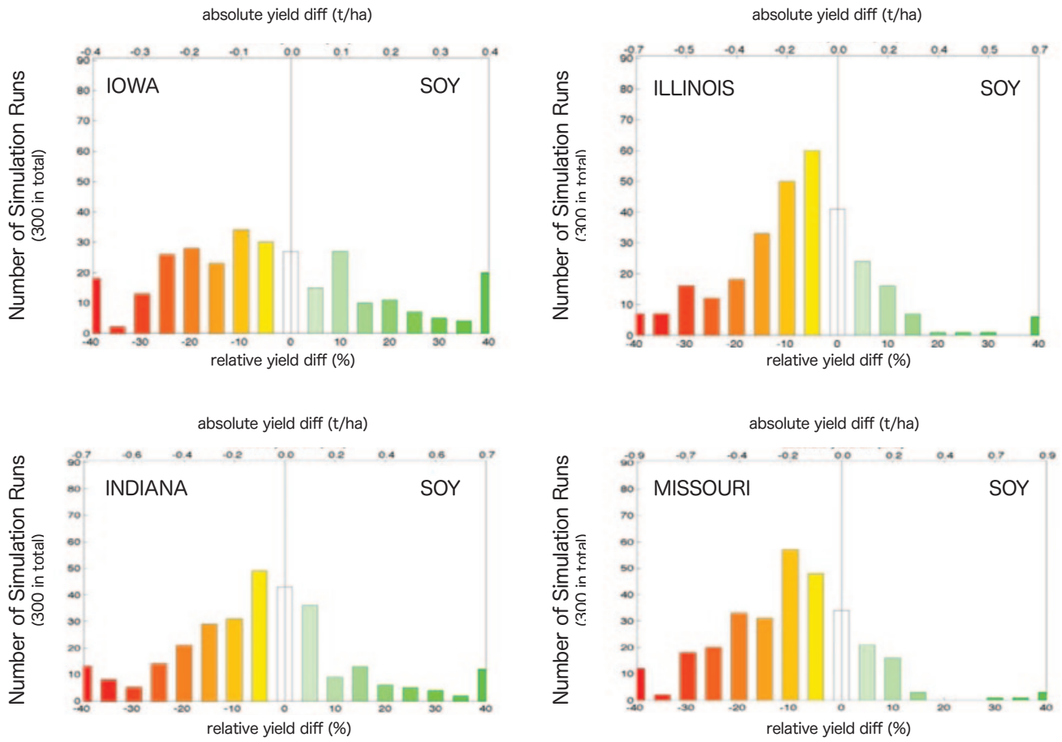


Figure 4. Declines in US soy production. The graphs were generated using the same methodology as in Figure 2 on pg. 5. [Figure 7 from Ozdogan et al.[6]]

The impact on agricultural production

Two studies conducted in 2011 examined how these climate alterations would affect agricultural output. Ozdogan et al[6] examined the impact on corn and soybean production in the US Corn Belt where more than 70% of US grain is produced. Localized climate data were generated for four separate sites in the Corn Belt, one each in Indiana, Illinois, Iowa, and Missouri (Figure 1).The study used a comprehensive terrestrial ecosystem model, the Agro-Integrated Biosphere Simulator (Agro-IBIS), to calculate the change in predicted yield for corn and soybeans at each of these sites for the 10 years following a limited nuclear war in South Asia. The calculated change in crop yield was based on the decline in precipitation, solar radiation, growing season length, and average monthly temperature predicted in Robock's study.

The calculations in this initial study are probably conservative, as the study did not consider two other environmental factors, which would be expected to produce a further significant decline in yield. It did not factor in the increase in UV light secondary to ozone depletion, and, perhaps more importantly, it did not consider daily temperature extremes, which may lead to complete crop failure. The observed weather following the Tambora eruption suggests that these daily extremes may be the largest determinant of total crop losses. The average global deviation in temperature in 1816 was only -0.7°C, but there was significant shortening of the growing season.

In the northeastern United States and eastern Canada, which were particularly hard hit, temperatures were actually above average during the early part of the year, and even during the summer months there were a number of periods with average or above average temperatures. But four severe cold waves, June 6-11, July 9-11, and August 21 and August 30, brought killing frosts as far south as the Mid Atlantic States, and in New England and Quebec there was even significant snow fall in June.[7] These periods of frost caused extensive damage to crops. A similar pattern in Northern Europe caused crop losses in the range of 75%[8] and the last multi-country famine in European history. In addition, the study did not consider several other factors, which might limit food production. Modern agriculture is very dependent on gasoline to power tractors and irrigation pumps and to transport produce to market, and on other petroleum products used in the manufacture of fertilizer and pesticides.

A major conflict in South Asia would be very likely to affect petroleum supplies and prices, which would have an additional negative impact on agricultural output. Further, given the intense demand for petroleum products, some of the grain produced might be diverted to ethanol production to try to offset the shortfall in petroleum. Despite this conservative bias, the study showed very significant declines in both corn and soybean production. Averaged over 10 years, corn production would decline by 10% at all four sites (Figure 2). But there would be a great deal of variation from year to year, and losses would be most severe in year 5, averaging more than 20% (Figure 3). For soybeans there would be a similar decline averaged over 10 years (Figure 4). Here, too, the losses would be most severe in year 5, again averaging more than 20%.

In a separate study, Xia and Robock[9] examined the decline in Chinese middle season rice production in response to this 5 Tg event. This study used a different model, the Decision Support System for Agrotechnology Transfer model 4.02 (DSSAT). It is a dynamic biophysical crop model and simulates plant growth on a per hectare basis, maintaining balances for water, carbon and nitrogen. The required inputs include the plant environment (weather and soil), cultivar genotypes and agricultural management practices. The

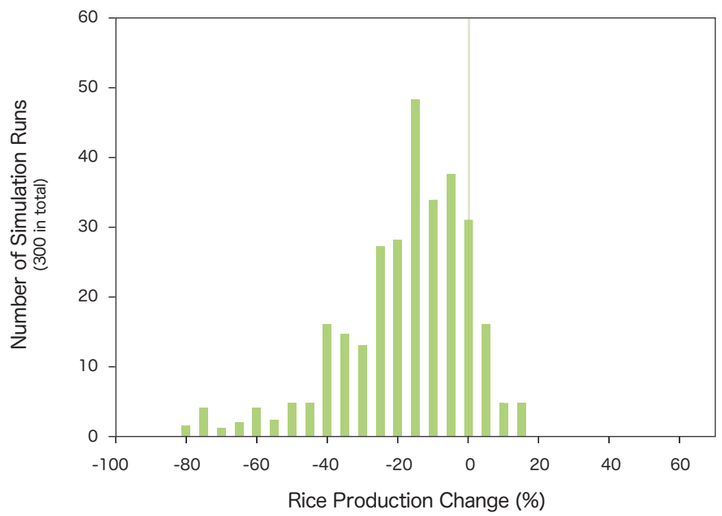


Figure 5. Distribution of rice production charge (%): The gray area shows ± standard deviation from the control runs, illustrating the effect of interannual weather variations. [Figure 2(b) from Xia and Robock[9]]

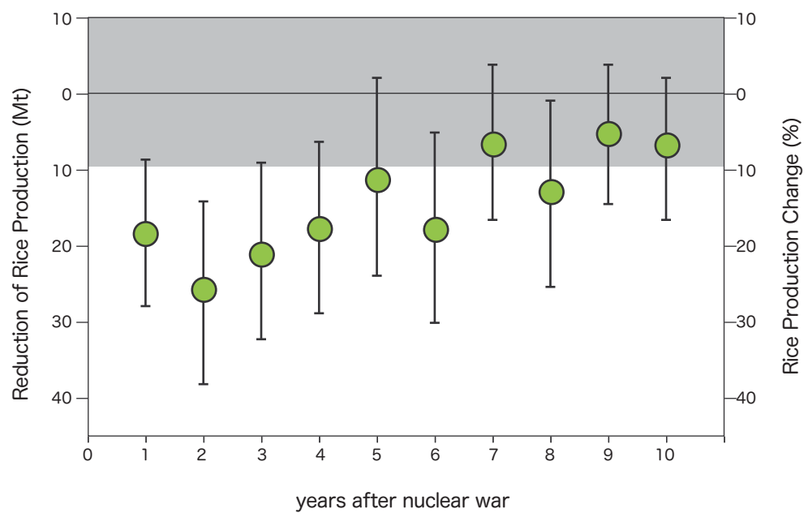


Figure 6. Reduction of rice production with whiskers showing one standard deviation for each year after the nuclear war. The gray area shows ± 1 standard deviation from the control runs, illustrating the effect of interannual weather variations. [Figure 2(a) from Xia and Robock.[9]]

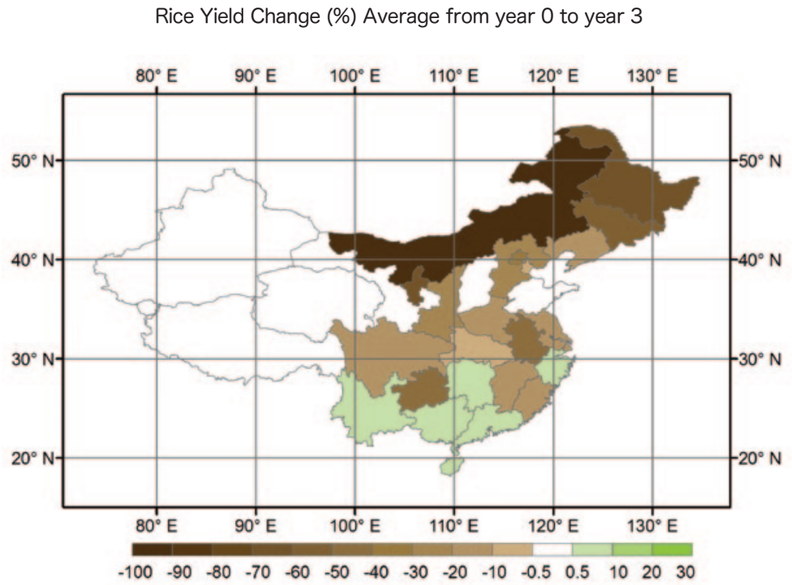


Figure 7. Map of rice yield reduction (%) forthe first 4 years after regional nuclear conflict. Brown indicates negative change, and green indicates positive change. White regions are provinces for which we did not conduct model simulations. [Redrawn from Figure 5 of Xia and Robock.[9]]

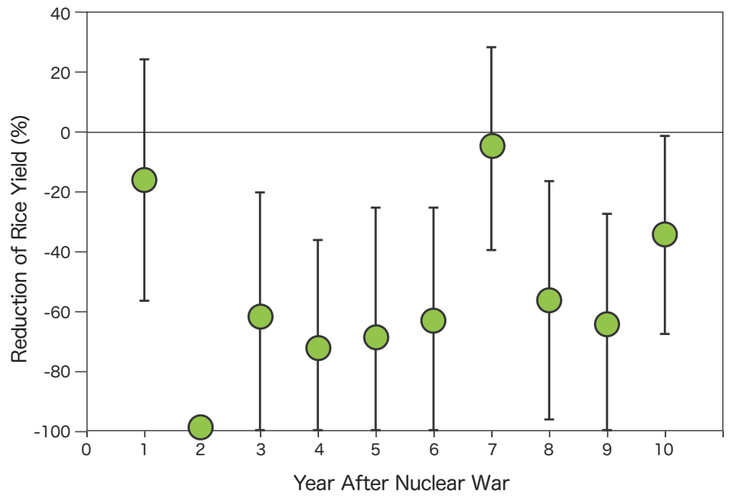


Figure 8. Reduction of rice yield over time in Heilongjiang Providence, with whiskers showing one standard deviation for each year after the nuclear. [Redrawn from Figure 6 of Xia and Robock.[9]]

outputs from this model are potential yields, which are usually higher than actual yields. Perturbed climate data in 24 provinces in China were generated using predictions of climate change from Robock et al. and observations in China from 198 weather stations from 1978 to 2008 (China Meteorological Data Sharing Service System). The simulated change in middle season rice yield in China was due to the predicted decline in average monthly precipitation, solar radiation and temperature.

This study also did not consider the effect of UV light increases or daily temperature extremes, or the possible decline in available fertilizer, pesticide and gasoline. Again, despite this conservative bias, the study showed a significant decline in Chinese middle season rice production. Averaged over 10 years, the decline would be about 15% (Figure 5). During the first 4 years, rice production would decline by an average of 21%; over the next 6 years the decline would average 10% (Figure 6). The impact on rice production was found to vary widely by province (Figure 7). In some areas in the South and East of China, production would actually rise. For example, in Hainan rice yield would increase by 5 to 15% per year. In other areas to the North and West the decline would be much more severe than the national average. In Heilongjian province, home to 36 million people, there would be a complete failure of the rice crop in year 1 following the war. Rice production would remain 60 to 70% below baseline for most of the rest of the following decade (Figure 8).

The impact on human nutrition and health

The world is particularly vulnerable at this time to a major decline in food production. In March 2012, the UN Food and Agriculture Organization estimated that grain stocks were 518 million metric tons, 22% of the annual consumption of 2,319 million metric tons.[10] Expressed as days of consumption, this reserve would last for 80 days. The US Department of Agriculture estimates were somewhat lower at 467 million metric tons of grain stocks, a mere 19% of their estimated annual consumption, of 2,299 million metric tons.[11] Expressed as days of consumption, this reserve would last for only 68 days. Furthermore, the UN Food and Agriculture Organization estimated in 2010 that there are 925 million people in the world who already suffer from malnutrition.[12]

Given this precarious situation, even small further declines in food production could have major consequences. The large and protracted declines in agricultural output predicted by Ozdogan and Xia are unprecedented in modern times, and the full extent of their impact on human nutrition is difficult to predict.

Normally a decline in agricultural production affects food consumption by raising the cost of food; the decline in "accessible" food, the amount of food that people can afford to buy, is much greater than the decline in "available" food, the actual agricultural output. The impact of rising food prices is, of course, felt disproportionately by people who are already malnourished precisely because they cannot, at baseline prices, afford to buy enough food.

A 2011 study by Webb et al[13], drawing on the data generated by Ozdogan, attempted to estimate the effect that the shortfall in agricultural output following a limited nuclear war would have on the price of food, and therefore on its accessibility. Using a global economy-wide model, the Global Trade Analysis Project (GTAP), the study examined the effects on food prices, and the numbers of people who are malnourished. In order to simulate the shock's effect on cereal and soybean prices, the study assumed that all crops produced globally suffer yield declines to the same extent that Ozdogan predicts for maize and soybeans in the US corn belt. The study found that the rise in food prices associated with the average yearly decline in food production would cause an additional 40 million people to become malnourished, and that the largest annual decline in food production in year 5 would cause 67 million to enter the ranks of the malnourished. The cumulative effect over 10 years would cause a total of 215 million people to become malnourished. The study concluded that a one year 20% decline in crop yield would cause crop prices to rise 19.7%. But this rise would be very unevenly distributed across the globe. In East Asia the rise would be 21.4% and in South Asia 31.6%. The relationship between crop yield and food prices is not linear: a further decline in yield would lead to a much larger increase in prices. While the current crop studies do not predict a decline of 40%, should that occur, it would cause global crop prices to rise an average of 98.7%. Again the price rise would be very uneven.
In South Asia, as a whole, prices would rise 140.6%, and in India 159.6%.

The impact of rising food prices is, of course, felt disproportionately by people who are already malnourished precisely because they cannot, at baseline prices, afford to buy enough food.

It is hard to calculate with certainty the effect of these price rises on caloric intake, but the study argues that, "There is a broad consensus in the literature that this parameter [the percentage change in caloric intake given a one percent increase in the price of food] is approximately -0.5." So a one-year decline in crop yield of 20% worldwide would lead to a 19.7% rise in prices and a 10% decline in caloric intake. The much larger increases in food prices in some areas that are predicted in the study would therefore be expected to have a profound effect on the number of calories that people are able to consume.

A number of factors suggest that the accessible food for those who are already malnourished would decline even more dramatically than these numbers suggest. The GTAP model looks only at market behavior and assumes that markets behave "normally." In fact, experience suggests that, in the aftermath of nuclear war, markets would not behave normally. As the authors explain, "Markets react…with commodity speculation, hoarding (withholding of products from the market), or by seeking to capture market share through private non-open market deals (a loss of transaction transparency), each of which contributed to higher price volatility and market uncertainty" in recent years. For example, in March 2008, global wheat prices leaped 25% in a single day; in the following month the price of rice rose 50% in just two weeks.[14]

These transient jumps in price were prompted by events far less significant than a nuclear war. At the time of the great Bengal famine of 1943, during which three million people died, food production was only 5% less than it had been on average over the preceding five years, and it was actually 13% higher than it had been in 1941 when there was not a famine. But in 1943, after the Japanese occupation of Burma, which had historically exported grain to Bengal, the decline in food production was coupled with panic hoarding, and the price of rice increased nearly five fold, making food unaffordable to large numbers of people.[15] These two factors, hoarding and the severe increase in rice prices, caused an effective inaccessibility of food far more severe than the actual shortfall in production.
We would have to expect panic on a far greater scale following a nuclear war, even if it were a "limited" regional war, especially as it became clear that there would be significant, sustained agricultural shortfalls over an extended period. It is probable that there would be hoarding on an international scale as food exporting nations suspended exports in order to assure adequate food supplies for their own populations. In the last decade there have been a number of examples of nations banning grain exports. In September 2002, Canada faced with a sharp decline in wheat production because of drought conditions, suspended wheat exports for a year. The next year the European Union took similar action, as did Russia. And in August 2004, Vietnam indicated it would not export rice until the following spring.[16] India banned rice exports in November 2007 which, followed by export rice restrictions in Vietnam, Egypt, and China in January 2008, contributed to historic increases in world rice prices. In 2010, Russia, responding to the severe drought conditions that year, again suspended grain exports.[17]

In the event of a regional nuclear war, the grain exporting states would be faced with major crop losses and the prospect of bad harvests for the next several years. It is probable that they would take similar action, and refuse to export whatever grain surplus they might have, retaining it instead as a domestic reserve. It is also probable that there would be widespread speculation on agricultural markets. Given these potential disturbances in normal market conditions, it is possible that the increases in food prices could be much larger than predicted by the Global Trade Analysis Project (GTAP) model used in the Webb et al study. Even if we do not take into account the way that rising food prices exacerbate the effects of a fall in food production, the declines in available food predicted by Ozdogan and Xia would be devastating.

The agricultural disruption caused by a limited nuclear war would also pose a threat to the several hundred million people who enjoy adequate nutrition at this time, but who live in countries that are dependent on food imports.

For the 925 million people who are currently malnourished, the majority of their caloric intake is derived from grain. For example, in Bangladesh the figure is about 78%. We cannot know with certainty that a 10-20% decline in grain production would translate directly into a 10-20% decline in grain consumption for all 925 million. Some of the malnourished are subsistence farmers who live in areas where grain production might not decline. But we do know that the chronically malnourished cannot survive a significant, sustained further decline in their caloric intake. With a baseline consumption of 1,750 calories per day, even a 10% decline would lead to an additional deficit of 175 calories per day.
While many of the malnourished might survive the first year, it is realistic to fear that they would not survive if these conditions persisted for a decade. Even if minimal, life-sustaining, levels of calories could be provided for all of the malnourished, the decline in quality of nutrition would cause significant health effects. As Webb et al point out in their study:

> *As food prices rise people spend relatively more on staples and less on 'quality' foods (which tend to be micronutrient rich, including meat, eggs, vegetables, etc.)… The specific impacts of reduced diet quality as well as quantity include a rise in wasting among children under 5, maternal undernutrition (low body mass index) which can also cause irreversible damage to the fetus and a rise in rates of low birth weights, and outbreaks of micronutrient deficiency diseases that may be killers in their own right… Based on such experiences, one can assume that any large food price increases attendant on a nuclear shock would result in similar shifts in household consumption globally (not only in South Asia) away from nutrient-rich, higher cost foods towards core staples (with a view to buffering at least a minimum energy intake). There are insufficient data to allow for the more complex modeling required to estimate resulting nutrition outcomes in terms of increased micronutrient deficiencies, maternal nutritional compromise or low birth weight. However, it is clear that the human impacts would be huge—with impaired growth and development of children, increased morbidity (due to failing immune functions caused by malnutrition), and a rise in excess mortality.*[18]

The agricultural disruption caused by a limited nuclear war would also pose a threat to the several hundred million people who enjoy adequate nutrition at this time, but who live in countries that are dependent on food imports.
The nations of North Africa, home to more than 150 million people, import more than 45% of their food.[19] Malaysia, South Korea, Japan and Taiwan, as well as a number of countries in the Middle East, import 50% or more of their grain.[20] The anticipated suspension of exports from grain growing countries might cause severe effects on nutrition in all of these countries. The wealthier among them might initially be able to obtain grain by bidding up the price on international markets, but as the extent and duration of the crop losses became clear, exporting countries would probably tighten their bans on exports threatening the food supplies of all these importing countries. Combined with the 925 million people who are currently malnourished, the populations of these food importing countries place the number of people potentially threatened by famine at well over one billion.

Two other issues need to be considered as well. First, there is a very high likelihood that famine on this scale would lead to major epidemics of infectious diseases. The prolonged cooling and resultant famine in 536-545 AD was accompanied by a major outbreak of plague which developed over the next half century into a global pandemic.[21] The famine of 1816 triggered an epidemic of typhus in Ireland that spread to much of Europe[22] and the famine conditions in India that year led to an outbreak of cholera that has been implicated in the first global cholera pandemic.[23] The well studied Great Bengal Famine of 1943 was associated with major local epidemics of cholera, malaria, smallpox, and dysentery.[24]
Despite the advances in medical technology of the last half century, a global famine on the scale anticipated would provide the ideal breeding ground for epidemics involving any or all of these illnesses. In particular, the vast megacities of the developing world, crowded, and often lacking adequate sanitation in the best of times, would almost certainly see major outbreaks of infectious diseases; and illnesses, like plague, which have not been prevalent in recent years might again become major health threats. Finally, we need to consider the immense potential for war and civil conflict that would be created by famine on this scale. Within nations where famine is widespread, there would almost certainly be food riots, and competition for limited food resources might well exacerbate ethnic and regional animosities. Among nations, armed conflict would be a very real possibility as states dependent on imports attempted to maintain access to food supplies.

The vast megacities of the developing world, crowded, and often lacking adequate sanitation in the best of times, would almost certainly see major outbreaks of infectious diseases; and illnesses, like plague, which have not been prevalent in recent years might again become major health threats.

It is impossible to estimate the additional global death toll from disease and further warfare that this "limited regional" nuclear war might cause, but, given the worldwide scope of the climate effects, the dead from these causes might well number in the hundreds of millions. The newly generated data on the decline in agricultural production that would follow a limited, regional nuclear war in South Asia support the concern that more than one billion people would be in danger of starvation. Epidemic disease and

further conflict spawned by such a famine would put additional hundreds of millions at risk. These findings support the following recommendations:

Conclusions and recommendations

The newly generated data on the decline in agricultural production that would follow a limited, regional nuclear war in South Asia support the concern that more than one billion people would be in danger of starvation. Epidemic disease and further conflict spawned by such a famine would put additional hundreds of millions at risk. These findings support the following recommendations:

1) There is an urgent need for further study to confirm the declines in corn and rice production predicted by Ozdogan and Xia, and to examine the effect on other key crops, such as wheat, and in other important food producing countries.

2) There is a need to explore in more detail the subsequent effects that these shortfalls would have on human nutrition including both the extent of the decline in caloric intake that would result from these crop losses and the extent of micronutrient deficiencies that would, in turn, result from this decline in caloric intake.

3) The need for further study notwithstanding, the preliminary data in these studies raises a giant red flag about the threat to humanity posed by the nuclear arms race in South Asia and by the larger and more dangerous nuclear arsenals possessed by the other nuclear weapons states. There is an urgent need to reduce the reliance on nuclear weapons by all nuclear weapons states, and to move with all possible speed to the negotiation of a treaty that will ban nuclear weapons completely.

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Impact on economy and development

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Estimating the economic consequences of a nuclear weapons explosion: Critical factors

Dr. Lloyd J. Dumas and Dr. Teresa D. Nelson

Credit: Bigstock Photo

Introduction

Whether it is the result of an accident, an act of terrorism, or a military attack, the explosion of a nuclear weapon on the territory of any nation would be a matter of grave concern, not only to that nation but to the world at large. Such a traumatic event would have profound psychological, political, and social consequences, but it would also certainly impose potentially enormous economic costs on the nation in which it occurred. In this increasingly interconnected global economy, these costs would likely reach far beyond that nation's borders. Fully understanding the implications of a nuclear weapons explosion therefore requires an appreciation of the type and magnitude of shock the explosion would deliver to the economic system.

While the physical effects of the explosion of a single nuclear weapon are relatively straightforward and have long been understood, estimating the economic consequences is a much more complex, contingent, and interdependent problem. There are three broad categories of costs: 1) those related directly to the destruction the bomb causes; 2) those related to economic disruption that a detonation creates; and 3) those related to the reaction an explosion provokes. *Destruction* costs include the loss of productive economic activity due to the injury and death of the human victims; the damage done to equipment, buildings and other physical structures, including key elements of the economic infrastructure (such as power plants, roads, water supply, and waste treatment systems); decontamination, decommissioning, and debris disposal; and the costs of evacuating and sheltering survivors. *Disruption* costs include the loss of key suppliers to or customers of economic enterprises outside the zone of destruction; damage to critical nodes of the power grid, the financial system, and the communications and transportation networks, among others; and the loss of key facilities and personnel with critical skills (such as hospitals and health care professionals) on which those outside the zone of destruction also depend. *Reaction* costs include the cost of increased safety, security and surveillance measures aimed at preventing future occurrences; loss of privacy, freedom of movement and perhaps other freedoms associated with those measures; and costs related to any actions taken against those believed responsible.

Along with being affected by the size of the weapon involved, all of these costs are affected to a greater or lesser degree by whether the explosion is the result of an accident, a terrorist act, or a military attack.[1] At first thought it might seem that destruction costs would depend on the size of the weapon, not the nature of the incident. However, the nature of the incident profoundly affects where the explosion occurs. An accident could happen almost anywhere nuclear weapons are stored, deployed, or moved. Some locations might be fairly remote and would tend to have relatively low damage costs associated with them; other locations are much closer to centers of population and economic activity and would impose much higher costs. But terrorist or military targets would be deliberately chosen to try to impose heavy costs on the targeted nation. The same reasoning also applies to disruption costs. Similarly, reaction

costs would be very different if the explosion were the result of an accident rather than a terrorist or a military attack.

The major physical effects of a nuclear weapons explosion include blast, fire, prompt radiation, radioactive fallout, and electromagnetic pulse (EMP). Blast and fire, which depend on the power and design of the weapon involved, are responsible for the damage done to physical structures in the strike zone, and together with prompt radiation from the burst itself, for much of the death and injury of people within that zone. They are therefore a major source of destruction cost. Radioactive fallout spreads out in a plume from the site of the explosion, the size and direction of which depends on the power of the weapon and prevailing winds. It may cover an area of hundreds of miles from the detonation.[2] Depending on the dose they receive, fallout can kill, sicken, or shorten the lives of those people exposed.[3] While it does little if any direct damage to buildings and other physical structures, it can so contaminate them with radiation as to make their use problematic, if not impossible for an extended period of time. It can also prevent first responders from entering areas within the zone of destruction to put out fires and rescue trapped individuals, thus increasing the damage done by the strike, and with it, destruction costs. An EMP, essentially a powerful voltage surge, does not kill people or destroy structures, but is strong and fast enough to permanently disable most modern electronic equipment on which our economic system and way of life increasingly depend. The extent of damage done by the EMP depends strongly on the height at which the weapon is detonated, as well as its power and design.

Economic costs of destruction

The attack launched against the World Trade Center on the edge of New York City by terrorists on 11 September 2001 and the assault launched against the Gulf Coast of the United States and the City of New Orleans by Hurricane Katrina on 29 August 2005 represent recent major disasters that can provide us with some insight into the type and magnitude of destruction costs likely to be imposed by the explosion of a nuclear weapon in a populated area. Studies done of'nuclear weapon, it would have been turned into rubble so quickly that no one would have had the chance to escape, and tens of thousands would have died. With a death toll of 40,000—a plausible estimate of the number of people working in or visiting the World Trade Center complex that day—even valuing incomes at the average level for New York City would raise the economic cost of lost earnings of those killed in the attack to more than $30 billion.[5] And, depending on the power of the weapon used, many thousands more people in the vicinity (but not actually on the campus of the World Trade Center complex) would have been killed, multiplying the economic cost involved.

In the event of a nuclear explosion, there would also be earnings losses directly related to jobs lost by survivors or reductions in the number of hours they work. These losses would occur in or near the strike zone, spreading out geographically depending on the extent of fire and the size and direction of the radiation plume. Levels of job loss across industries would depend on an industry's presence in the zone of destruction. Some industries might reabsorb surviving workers elsewhere, others might not, potentially adding to regional and perhaps national unemployment levels.
For the 9/11 attack, the Federal Reserve Bank of New York estimated these losses at "$3.6 billion to $6.4 billion in reduced wages and salary income in city industries affected by the attack."[6] Within 13 months of Hurricane Katrina's inundation of 80 percent of the City of New Orleans, "still ongoing economic losses" were already estimated at $4–$8 billion, out of "an aggregate monetary loss of $40–50 billion in Orleans Parish," according to a paper published by the US National Academy of Sciences.[7]

A variety of factors would contribute to a reduction in worker productivity in the vicinity of the site of a nuclear weapons explosion. There are effects on the physical health of survivors as well as effects on mental/emotional health, such as psychological stress (including post-traumatic stress disorder, PTSD), depression and a loss of confidence. Immediate or near term access to appropriate health care services could affect productivity over the longer term. If health clinics or hospitals were heavily damaged or destroyed and/or key health care workers injured or killed—as is highly likely in the case of a military or terrorist nuclear attack targeting a densely populated area—attention to the health needs of survivors in or near the strike zone would be greatly diminished, especially if conditions (such as radiation levels) make it difficult for outside responders to gain access. This would magnify short and perhaps long term productivity losses, and therefore associated economic costs.

Destruction of physical capital (structures, facilities, and equipment) and inventories would be extensive in the immediate area of the explosion. Radioactive contamination would render intact facilities and equipment unusable within the potentially extensive radiation plume for a period of time ranging from days to years until radiation levels naturally decay or are sufficiently reduced by purposeful decontamination. The ability to use existing structures or equipment would also depend on whether or not they can be repaired at reasonable cost. For producers, loss of physical capital includes damage to or destruction of office space, industrial centers, research facilities, transport centers, and associated equipment. For consumers, losses include damage to or destruction of their homes, vehicles, schools, and places of worship. Both will incur costs due to the loss or damage to retail space, public transportation infrastructure, as well as components of the power grid and communication networks, and water and waste treatment facilities.

According to the Federal Reserve Bank of New York's published analysis of the 9/11 attack costs, "The cost of replacing destroyed or damaged buildings in the World Trade Center complex and adjacent areas is estimated to be $11.2 billion…. The cost of replacing the contents of the destroyed buildings, including the technology and fixtures, has been estimated to be $5.2 billion."[8] Including the repair of communications, transportation, and power infrastructure, "the total physical losses sustained in the attack [are estimated] to be about $21.6 billion."[9] That is within the $20–$22 billion range of the estimate of direct property losses caused by Hurricane Katrina in Orleans Parish.[10] It is likely that an accident, terrorist assault, or military attack involving the explosion of a single nuclear weapon would do considerably more damage to physical capital than that in a city like New Orleans, and destroy many times that much physical capital in a city like New York.[11]

The economic costs of recovery include more than the replacement of structures, machinery, and equipment and the care of injured survivors. It also includes costs associated with the type and availability of machinery, vehicles, and workers needed to gather and dispose of or store the wreckage and debris. This is by no means a trivial matter. The attack on the World Trade Center generated nearly 3 million cubic yards of debris—a substantial amount of which was potentially damaging to the health of those tasked with the cleanup. But that was dwarfed in sheer volume by the estimated 100 million cubic yards of debris generated by Hurricane Katrina over its entire zone of destruction along the Gulf Coast.[12] In addition to the enormous volume of debris that would be generated, laden with whatever toxic chemicals it might contain, a nuclear explosion would add the necessity of radioactive decontamination to the cleanup task. Depending on cleanup standards, mitigating radioactive contamination could add a great deal to the economic costs involved.

In 2005, Reichmuth et.al. conducted an analysis for the Pacific Northwest National Laboratory of the economic consequences of an attack with a single nuclear weapon.[13] Their study was focused on the sensitivity of the costs imposed to the cleanup standards involved. They considered a range of nuclear weapons sizes (0.7kT, 13 kT, and 100kT) along with a large "dirty bomb"—a device designed to scatter radioactive contamination without a nuclear explosion. Five potential targets were considered, ranging from a rural town to a high-density urban area. Then they evaluated the costs associated with five levels of post-attack decontamination, ranging from reducing radioactive exposure to a continuing 15 millirems per year (a relatively stringent standard set by the Environmental Protection Agency) to a much less rigorous cleanup standard of 5,000 millirems per year exposure (a Nuclear Regulatory Commission standard for workers). Assuming offsite disposal of radioactive waste, their estimates of the costs of decontamination and decommissioning ranged from $93 million per square kilometer for farm or range land to $2.7 billion per square kilometer for a high density urban area.[14] Their overall conclusions? For an attack with a nuclear weapon or large "dirty bomb", "economic consequences … are highly dependent upon and closely coupled to the cleanup level selected.… Because such an event could potentially spread contamination very widely, even an event in a 'remote' location could have huge economic consequences."[15]

The cost of disruption

As sensitive as the costs of *destruction* are to the site of a nuclear weapon's explosion, the costs of disruption may be even more sensitive. They depend on precisely how the area struck fits into the local, national, and global economic network. An explosion that severely damages or destroys a critical node of that network where key economic activities take place will cause far more disruption than an explosion that cripples a node the economic function of which is either relatively marginal or easily duplicated. Critical nodes of the economic system include major transportation hubs; areas where there is a concentration of suppliers of fuels, electricity, or manufactured components vital to key industries; and financial centers.

For example, taken together the ports of Los Angeles and Long Beach in southern California make up "the third busiest port in the world, which handles 14.2 million 20-foot unit equivalent containers annually with a value of about $295 billion."[16] An estimated 44 percent of all the imports entering the United States come into the country through one or the other of these two nearby ports.[17] Even without a nuclear explosion, the detonation of a radiation dispersing "dirty bomb" could shut down the ports because the resultant radioactive contamination would necessitate extensive and disruptive decontamination procedures, which along with unacceptable radiation levels, make it impossible or unwise for workers to return to the docks for an extended period of time. Rosoff and Winterfeldt have estimated that an attack with a dirty bomb could feasibly cause a four-month to one-year shutdown of these ports that would impose costs of $63 billion to $252 billion. Those costs would be the result of "the economic impacts of a delay of delivering goods as well as all ripple effects throughout the nation's economy that such long-term delays involve. This includes costs ranging from the loss of local dock worker jobs to the reduced income and possible forced closure of nationwide businesses not receiving necessary parts or retail products."[18]

In September 1999, a 7.6 magnitude earthquake hit the island of Taiwan, temporarily crippling economic activity there. Taiwan, and in particular the industrial city of Hsinchu south of Taipei, was a key global center of manufacturing of semiconductor chips, virtually a "raw material" of the extensively interlinked global electronics industry. "Within days, assembly lines across Asia and the United States began to seize up, due to a break in the flow of semiconductors out of Hsinchu…. [T]he cut-off—which lasted about a week—left many electronics production systems snarled for months."[19]

After the 9.0 magnitude Tohoku earthquake and resulting tsunami of 2011, "Japan's industrial output fell an astounding 15.3 percent, almost double the previous record fall…" Nearly 90 percent of that drop in Japanese industrial output constituted economic disruption beyond the disaster zone itself. The fall-off in output outside of Japan after that disaster "was sudden, dramatic and widespread. Countries as diverse as South Korea, China, the Philippines, Taiwan, Singapore, Thailand, Germany, France and the UK all reported closely interlinked plunges in production. In the United States, … [the] Federal Reserve reported record downturns in production; the Philadelphia Fed Manufacturing Index, for instance, registered the biggest three-month collapse ever."[20] Production was disrupted in a

wide variety of industries around the globe, "including personal computers, mobile telephones, electronics, appliances, robotics, telecommunications gear, specialty steel, photovoltaics, and chemicals. The world automotive industry alone saw production plummet some 30%, for more than three months."[21]

Because the Tohoku earthquake/tsunami of 2011 struck the relatively lightly industrialized north of Japan, it was expected to cause little economic disruption compared to the great Kobe earthquake of 1995 in the nation's more heavily industrialized south. But in the 16 years between the two, the global economy had grown considerably more dependent on fewer sources of supply, magnifying the impact of any major disaster striking any critical node of the global economic network. As a result, the explosion of a nuclear weapon, whether by accident or intention, in one of these critical areas would not only cause much more injury and death, but also potentially enormous economic disruption. Depending on the size and design of the weapon, even with an extensive (and expensive) decontamination and reconstruction effort, that critical node could be taken out of action for months, years, or longer.

The Gulf Coast of the US is a zone of concentrated production and processing of nonrenewable fuels on which the economy of the US and wider world still primarily depend. According to the US Energy Information Administration, "The Gulf of Mexico area, both onshore and offshore, is one of the most important regions for energy resources and infrastructure…. Over 40 percent of total U.S. petroleum refining capacity is located along the Gulf coast, as well as 30 percent of total U.S. natural gas processing plant capacity."[22] Furthermore, "The oil and natural gas industry currently supplies more than 60% of the nation's total energy demands and more than 99% of the fuel used by Americans in their cars and trucks, while 900 of the next 1000 U.S. power plants are projected to use natural gas…. The oil and natural gas industry is one of the largest employers in the country."[23]

Even if only a portion of Gulf Coast production and refining capacity were lost in a nuclear strike, given the extent to which the US depends on refined petroleum for transportation and natural gas for other critical uses, a severe jolt would be delivered to the nation's economy. The US economy relies on foreign sources for nearly half of foreign petroleum and petroleum liquids. Should an attack remove 5% of refined crude oil, the US economy would become more dependent on the availability of refined petroleum from abroad. Initially, until these imports began flowing into the US, the strike would cause shortages of gas and oil, and undoubtedly lead to both higher prices and rationing. One only has to remember the OPEC oil embargo of the mid-1970s to get a sense of this effect on prices of goods manufactured in the US, costs of travel, and the difficulty of finding gasoline. If the shock of such a nuclear explosion did not initially bring the country to a standstill, it would be highly likely to produce very long lines and rising tempers at gasoline stations throughout much of the country, reminiscent of the days of the OPEC oil embargo, or of the 2012 aftermath of Hurricane Sandy in New York and New Jersey.[24] A nuclear strike could make recovery much more difficult than a political embargo or a natural disaster.

One of the less discussed effects produced when a nuclear weapon explodes is known as an electromagnetic pulse (EMP). Though not as dramatic or obvious as the blast, fire, and radiation effects, an EMP would wreak havoc on the electronic equipment on which the economy and our wider society have become thoroughly dependent. According to a paper published by the National Academy of Sciences,

> *The problems this pulse poses for electronic equipment are twofold. Electric power grids would pick up the EMP and transmit a transient spike in voltage to equipment drawing power at the time of the detonation. The rapid rise in voltage would damage microprocessors in a way similar to that resulting from lightning strikes. However, the rise in voltage would be typically 100 times faster, thereby rendering common surge protectors ineffective. Second, the electronic equipment itself could pick up the pulse and generate internally induced currents. The result could produce physical damage to the equipment.*[25]

The reach of the EMP effect depends on the altitude at which the nuclear explosion occurs. An explosion of a powerful nuclear weapon 21 kilometers or more above the earth could produce an EMP that would cover hundreds of thousands of square kilometers.[26] In fact,

> *A high-yield weapon detonated 200 miles (about 322 km) above Kansas would generate a pulse which would affect the entire country [contiguous U.S.] plus parts of Canada and Mexico. Furthermore, the entire region would be blacked out simultaneously, since the [EMP] radiation produced by the explosion travels at the speed of light…. The economic and social ramifications of disrupting a highly developed electronics network would be staggering. Not a single facet of the economy would escape the effects of an interruption to the normal flow of communications, data retrieval, and the accompanying capacity to process vast amount of information.*[27]

On the one hand, while this conclusion does refer to the case of a single weapons explosion, it applies to a high-yield weapon exploded at a very high altitude, a combination of conditions which is much more likely to hold in the case of military attack than to result from a nuclear weapons accident or terrorist attack. On the other hand, economies and societies today are far more dependent on sensitive electronics than they were in the mid-1980s when those words were written. And electronic components "fried" by an EMP would be rendered permanently useless and therefore have to be replaced.

According to the 2008 report of the EMP Commission, we could expect most personal and business computers to fail because they are not hardened against EMP. Based on simulations of an EMP attack, they would be "rendered permanently inoperable until replaced or physically repaired."[28] The Commission found, "[a] n EMP attack… potentially could achieve the NAS [National Academy of Sciences] criteria for financial infrastructure catastrophe: 'simultaneous destruction of all data backups and backup facilities in all locations.'"[29] They further argued that failure or widespread damage to any of ten critical infrastructures they identified would likely cause ripple effects throughout the others. These included banking and finance, electric power, petroleum and natural gas, telecommunications, transportation, food, water, and emergency services.[30]

The American military has made efforts to harden the electronics on which its critical systems depend, but it remains true that much of the electronics on which the general public and commercial industries depend on a daily basis are vulnerable to serious damage or destruction by EMP.

Reaction costs

Under any circumstances, the explosion of a nuclear weapon on the territory of any state would certainly provoke a reaction, but the type and extent of that reaction would be highly dependent on the surrounding circumstances. If it were the result of an accident involving the target country's own nuclear forces, there would certainly be a high priority investigation into the causes of the accident. Depending on what that investigation disclosed, there might be punishments meted out to those responsible. There would almost certainly be modifications to procedures followed in handling the weapons or even redesign of equipment (including the weapons themselves) in an effort to prevent such a disaster from ever recurring. But the costs of reaction would be relatively minimal compared to likely reactions in the event the detonation was the result of a deliberate terrorist or military attack.

The non-nuclear terrorist airborne attacks on the World Trade Center and the Pentagon on 11 September 2001 profoundly altered the US government and public's perceptions of what was required to keep the country safe, though those attacks did not do nearly as much damage as they would have had a nuclear weapon been involved. The clearly terrorist-driven events of 9/11 provoked an enormously expensive series of reactions. In addition to relatively low cost modifications of aircraft (e.g. special locks installed on the cockpit door), there were modifications in security measures ranging from the installation of expensive screening equipment and increased hiring of security personnel at airports around the world to time consuming boarding procedures. According to The Economist, citing a paper by Mueller and Stewart, "America has increased homeland security spending by more than $1 trillion in the decade since the 9/11 attacks…. By 2008, … America's spending on counterterrorism outpaced all anti-crime spending by some $15 billion."[31] Furthermore, "Mueller and Stewart do not even include things like the wars in Iraq and Afghanistan (which they call 'certainly terrorist determined') in their trillion-plus tally."[32]

Changes in airline travel have included longer lines, removing shoes and coats, limiting liquids, being screened and occasionally patted down or chemically screened, and the necessity for earlier arrival at airports. Given the huge volume of business-related air traffic, the cost of the additional time these procedures require has undoubtedly run into many billions of dollars since the attack. Even assuming that today's security procedures add "only a half-hour to passenger's travel time [and] that an hour of time is worth $50 for a business traveler and $15 for everyone else … Poole calculates that the annual cost … of the extra wait times … post September 11 … is about $8 billion" (emphasis added).[33] Robert Poole, a member of the Government Accountability Office's National Aviation Studies Advisory Panel, puts the total amount of money spent since 9/11 on screening passengers at $40 billion.[34]

However, the reality is that none of these costs are likely to equal the long-run costs of the wars in Afghanistan and Iraq launched by the US in reaction to the acts of terrorism committed on 11 September 2001. The most terrible cost of those two wars has been the hundreds of thousands of lives permanently damaged or destroyed, but the monetary costs are also enormous. Linda Bilmes and Joseph Stiglitz did an accounting of long-term monetary costs of the US-led 2003 invasion and subsequent occupation of Iraq alone. Going beyond the immediate costs, they included both direct and indirect expenditures, "such as lifetime healthcare and disability payments to returning veterans, replenishment of military hardware and increased recruitment costs." Setting aside the costs to all other participants (including Iraq), they estimated that the Iraq war by itself would ultimately cost the US from $1 trillion to $2 trillion.[35]

Even if a nuclear weapons explosion occurred as the result of a deliberate terrorist or military attack, rather than an accident, it is by no means certain that the country struck would react by launching lengthy war(s). But it is also by no means certain that it would not. If the explosion were the result of a military attack against a country that also possessed nuclear weapons, it is at least possible—perhaps likely—that the targeted country would feel compelled to respond in kind. Once a nuclear war is underway, a disaster beyond history is in the making, with immense economic and social costs.

Conclusion

Whether it is the result of an accident, a terrorist attack, or a military strike, the explosion of a single nuclear weapon on the territory of any nation would impose economic costs at least equivalent to, and most likely well beyond, the costs of a major natural disaster. Our past experience with large-scale natural and human-induced disasters tells us by analogy that the resulting economic costs depend strongly on the population density and the nature and extent of economic activities carried out in the zone surrounding the site of the explosion. In a key urban area, the costs of the immediate destruction and longer-term economic disruption inside and potentially far outside of that area could easily run into tens of billions—and possibly as high as hundreds of billions—of dollars.

Were this disaster to be the result of a deliberate attack, it is not difficult to imagine that extraordinary pressure would be generated for the government of the country struck to take some form of strong action in response. The additional economic costs imposed by that action would almost certainly be high, and should it degenerate into all-out war between two nuclear-armed rivals, the costs would be virtually incalculable.

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In sum, unless it occurred in a very remote, lightly inhabited and economically inconsequential area, the explosion of even a single nuclear weapon on the territory of any state as the result of an accident or deliberate attack would be a high-cost economic disaster, something we should bend our best efforts toward avoiding. But can such an event be permanently avoided in a world still populated with thousands of nuclear weapons, terrorist groups willing to use means of mass destruction, and an increasing number of nuclear-armed nations?

In 1996, the government-sponsored Canberra Commission, peopled by an impressive array of former high military and government officials from four of the then five major nuclear weapons states, issued its report.[36] The lengthy report argues, "The proposition that large numbers of nuclear weapons can be retained in perpetuity and never used—accidentally or by decision—defies credibility. The only complete defense is the elimination of nuclear weapons and assurance that they will never be produced again." [37]

The many billions of dollars of economic cost that even a single nuclear explosion in a major urban area would impose gives us one more reason to take seriously the call to move strongly and without delay toward the reduction and long overdue abolition of nuclear weapons.

Credit: Bigstock Photo

Notes:

1 There have been many major accidents relating to weapons of mass destruction. L.J. Dumas, *The Technology Trap: Where Human Error and Malevolence Meet Powerful Technologies* (2010), Santa Barbara, CA: Praeger/ABC-CLIO. See Chapter 4 for an analysis of such accidents and the Appendix to Chapter 4 for a listing of some 100 publicly reported serious accidents that occurred 1950–2009. See also Chapter 2 for an analysis of the prospects of terrorists acquiring nuclear weapons and other means to commit acts of mass destruction and the kinds of terrorist groups most likely to find such acts appealing.

2 For example, the radioactive plume from the explosion of a 100 kiloton (kT) nuclear weapon on San Ysidro in the far south of California could reach up to the southwestern corner of North Dakota. B. Reichmuth, S. Short and T. Wood, *Economic Consequences of a Rad/Nuc Attack: Cleanup Standards Significantly Affect Cost* (2005), Pacific Northwest National Laboratory, PNNL-SA-45256; April, p.8.

3 Excessive exposure to radiation sharply increases the risk of deadly cancer as long as decades after exposure.

4 J. Bram, J. Orr, and C. Rapaport, *Measuring the Effects of the September 11 Attack on New York City* (2002), FRBNY Economic Policy Review November, Federal Reserve Bank of New York, pp.5–6.

5 Ibid. Derived in part based on data in this source.

6 Ibid.

7 Kates, Colten, Laska, and Leatherman, *Reconstruction of New Orleans after Hurricane Katrina: A Research Perpective* (2006), *Proceedings of the National Academy of Sciences* of the United States of America, vol.103, no.40, National Academy of Sciences: October 3, 2006, pp. 14654-14655; www.pnas.org/cgi/doi/10.1073/pnas.0605726103

8 Bram et.al, Op.cit., p.11

9 Ibid.

10 Kates et.al, Op.cit., p.14655

11 At this writing, costs of the so-called "superstorm" Sandy that struck the northeast coast of the U.S. in late 2012 are still being assessed, but appear to rival those of Hurricane Katrina.

12 Boettke, Chamlee-Wright, Gordon, Ikeda, Leeson, and Sobel, *The Political, Economic and Social Aspects of Katrina* (2007), Southern Economics Journal vol.74, no.2: October 2007, p.364

13 Reichmuth et.al., Op.cit.

14 Ibid., Table 1, p.6

15 Ibid., p.12

16 R. von Winterfeldt, *A Risk and Economic Analysis of Dirty Bomb Attacks on the Ports of Los Angeles and Long Beach* (2007), Risk Analysis vol. 27, no. 3, p.536

17 Ibid.

18 Ibid., p. 543

19 Lynn, *Built to Break: The International System of Bottlenecks in the New Era of Monopoly* (2012), Challenge MagazineMarch/April 2012, p.89

20 Ibid., p.100

21 Ibid., p.101

22 *Gulf of Mexico Fact Sheet*, (not dated), U.S. Energy Information Administration; www.eia.gov/special/gulf_of_mexico/

23 *The Economic Impacts of the Oil and Natural Gas Industry on the U.S. Economy: Employment, Labor Income and Value Added* (2009), PriceWaterhouseCoopers,Prepared for the American Petroleum Institute, September 8, 2009, p.1 http://www.api.org/~/media/Files/Policy/Taxes/Economic_Impacts_on_Industry_Report_09082009.pdf

24 See for example, K. Zernike, *Gasoline Runs Short, Adding Woes to Storm Recovery* (2012) New York Times

25 Hal Cochraneand Dennis Mileti, *The Consequences of Nuclear War: An Economic and Social Perpective, In The Medical Consequences of Nuclear War* (1986), The National Academy of Sciences, pp.384-385

26 *The Effects of Nuclear War* (1979), Office of Technology Assessment, U.S. Government Printing Office, Washington, DC, p.22

27 Cochrane and Mileti, Op.cit., p.385

28 *Report of the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack: Critical National Infrastructures* (2008), Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack, Critical National Infrastructure, p.7, http://www.empcommission.org/docs/A2473-EMP_Commission-7MB.pdf

29 Ibid., p.90, citing National Academy of Sciences, *Making the Nation Safer: The Role of Science and Technology in Countering Terrorism (2002),* National Academy Press, Washington. DC, p.137

30 EMP Commission, Op.cit., p.10

31 N.B., *Deterring Terrorism. Is America Spending Too Much on Homeland Security?* (2011), The Economist. Gulliver. Business Travel, DC; www.economist.com/blogs/gulliver/2011/04/deterring_terrorism/. Citing J.Muellerand M. G. Stewart, *Terror, Security, and Money: Balancing the Risks, Benefits, and Costs of Homeland Security* (2011), prepared for the panel on "Terror and the Economy: *Which Institutions Help Mitigate the Damage?* at the Annual Convention of the Midwest Political Science Association, Chicago.

32 Ibid.

33 Bandyk, *What Airport Security Costs You*, (2010), U.S. News and World Report; http://money.usnews.com/money/business-economy/articles/2010/01/11/what-airport-security-costs-you

34 Ibid.

35 L. Bilmes and J. Stiglitz, *The Economic Costs of the Iraq War: An Appraisal Three Years After the Beginning of the Conflict*, Working Paper 12054, National Bureau of Economic Research, Cambridge, Massachusetts

36 Canberra Commission, *Report on the Elimination of Nuclear Weapons*; http://www.dfat.gov.au/publications/security/canberra-commission-report/index.html The Commission included: General George Lee Butler, former commander-in-chief of the U.S. Strategic Command, the officer in charge of all American strategic nuclear weapons from 1991-1994; Michel Rocard, Prime Minister of France from 1988-1991; Field Marshal Michael Carver, former chief of the British Defence Staff; Roald Sagdeev, former science advisor to the President of the Soviet Union; and Robert MacNamara, former U.S. Secretary of Defense and a key figure in developing the idea of security through "mutually assured destruction" that drove much of the nuclear arms race.

37 Ibid., Executive Summary, paragraph 2

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Impact on economy and development

Wider consequences – impact on development

Ray Acheson

This chapter will seek to explore how the use of nuclear weapons—whether a single detonation or a nuclear war—could exacerbate poverty and inequalities and undermine the achievement of the Millennium Development Goals (MDGs). The chapter will rely on data from other disasters, including natural disasters, the Chernobyl and Fukushima nuclear disasters, and nuclear testing in the Marshall Islands in order to extrapolate possible implications of the use of nuclear weapons on development. This chapter does not draw concrete conclusions because none of the aforementioned case studies or disaster scenarios have the same effects as the use of nuclear weapons. Instead, it will explain how disasters gravely exacerbate development challenges from reducing poverty to building infrastructure to promoting gender equality and will suggest how the use of nuclear weapons could have such effects.

Disasters and the economy

Disasters affect the achievement of development goals through loss of lives, livelihoods, and infrastructure, but also through the diversion of funds from development to emergency relief and reconstruction and broader effects on the economy.

The use of one or more nuclear weapons would in most cases have graver effects than those of natural disasters or other types of nuclear disasters.

Hypothesizing on the use of a 10-kiloton nuclear weapon on the Port of Long Beach in California, USA, a 2006 study by the RAND Corporation found that in addition to loss of lives and homes, damage to port and surrounding infrastructure, displacement of local residents, and the cost of worker compensation claims, there would also be severe impacts on the global shipping supply chain and thus the global economy. The authors argue that there would likely be an immediate call to close all US ports to incoming traffic and mass exodus from US port cities of local populations. Just the closure of the Long Beach port alone, which handles 30 percent of US shipping imports (by value in 2003), would lead to severe disruption of the supply of basic goods and petroleum in the United States. The port also handles about 7.5 percent (by value) of world trade activity. Thus, the authors note, "there is a high probability that the Long Beach scenario would have large economic consequences at great distances from the initial nuclear explosion."[1]

Dumas and Nelson further explore the economic consequences of a nuclear weapon explosion in this collection. What is important to note for this chapter is the relationship between the global economy and issues of development, poverty, hunger, and equality. The use of nuclear weapons would affect all of these issues independently and in the relationship between these issues and the global economy. Interruptions to the supply of food and petroleum within the country where the nuclear explosion has occurred; disruptions to the global supply of goods and the impact that has on the local economy, the business sector, and the stock market; damage to infrastructure, lives, and livelihoods; and resulting forced or voluntary migration—all of these have direct impacts on the levels of poverty and development in the affected country.

Global economic recession—a likely effect of the use of nuclear weapons—further undermines progress towards achieving the MDGs. Direct development aid is reduced due to perceived budget constraints in developed countries, while the recession also slows or ends economic growth in developing countries. The International Monetary Fund estimated that the global economy contracted by 0.6 percent in 2009[2] and that economies of developing countries contracted by 1.8 percent.[3] The World Bank estimated that an additional 64 million people would fall into extreme poverty as a result of the global recession.[4]

The broader context

As things stand now, projections indicate that by 2015 about one billion people will be living on an income of less than US$1.25 per day, the World Bank's measure of extreme poverty.[5] 22,000 children die each day due to poverty.[6] Nearly 870 million people suffered from chronic malnutrition in 2010–2012. The vast majority of these—852 million—live in developing countries.[7] The number of people living in slums has increased to an estimated 863 million people.[8]

Poverty, hunger, malnutrition, maternal mortality, child mortality, inadequate access to water, disease, environmental degradation, and lack of literacy and education are all persistent global challenges that require immediate, urgent, and sustained action. In September 2000, governments adopted eight Millennium Development Goals (MDGs), committing their countries to a new global partnership to reduce extreme poverty within a time-bound framework. The Goals include eradicating extreme poverty and hunger; achieving universal education; promoting gender equality and empowering women; reducing child mortality; improving maternal health; combating HIV/AIDS, malaria, and other diseases; ensuring environmental sustainability; and developing a global partnership for development.

However, the 2010 MDG Report produced by the United Nations warned that "unmet commitments, inadequate resources, lack of focus and accountability, and insufficient dedication to sustainable development have created shortfalls in many areas."[9] It is widely anticipated that most of the MDGs will not be met by the 2015 deadline.

While this is partially due to the failure of developed countries to meet their 0.7 percent aid pledges, it is also largely due to the concept and process of development promoted by the international financial institutions responsible for much of the aid to developing countries. Even as (inadequate) efforts are made to reduce poverty, inequality between the wealthy and the poor continues to rise. More than 70 percent of the world's income goes to 20 percent of the world's population. A 2011 study by UNICEF estimates that under the current rate of change it would take 800 years for the poorest billion people to achieve ten percent of global income.[10]

Development as envisioned by the mainstream financial institutions entails building institutions and implementing polices that allow for a country to participate in the global capitalist economy. However, given the inherent inequalities of economic globalization and the policies of international institutions that serve to entrench these inequalities through structural adjustment programmes and other neoliberal reforms, many countries continue to struggle to meet their objectives related to poverty, education, health, and more.

As the report Disaster risk reduction: a developmental concern argues, mainstream development models "place too much faith in the ability of unregulated markets to create favourable conditions for human development, pressure for reduction in state functions, an unfair global trading system which allows export 'dumping' and barriers to market access to persist, and inadequate and shrinking development assistance often deployed in the interests of donor countries."[11] UNICEF similarly questions the current development model, pointing out that it has allowed the wealthiest billion to accrue the most income. Its 2011 study argues that equity must be placed at the centre of the development agenda.[12]

Thus a nuclear explosion or nuclear war would take place in a context that is already challenging for meeting the MDGs and rife with international and domestic inequalities. And while a nuclear weapon explosion will not discriminate between rich and poor in its immediate impact, its long-term consequences will.[13]

Within countries, "the poorest populations are the most vulnerable to disasters as they are often left to settle on the riskiest locations and have least access to measures of prevention, mitigation and preparedness."[14] Disasters tend to exacerbate poverty because the poor are disproportionately affected by post-disaster inflation and by cuts in social spending.[15] After a disaster, most governments reallocate funds from capital and social expenditure to cover expenses related to clean-up and reconstruction and most donor countries reallocate resources from development to emergency relief.[16]

In the aftermath of any major disaster people are typically displaced from their homes for varying amounts of time. In developing countries in particular, displaced people often add to the swelling populations of urban informal settlements or end up in refugee camps, further undermining development strategies. A UK study suggests, "Lack of adequate livelihood resources in these new settlements can magnify risk as the immediate environment is exploited for resources such as firewood leading to soil loss and potentially increasing flood or landslide hazard." It also notes that high density living inside of camps and informal settlements increases exposure to disease.[17]

As has been shown in the Marshall Islands, Fukushima, and Chernobyl, displacement is a serious issue in the wake of a nuclear catastrophe. The inhabitants of the Marshall Islands became nomads, "disconnected from their lands and their cultural and indigenous way of life."[18] The tsunami, earthquake, and Fukushima Dai-ichi nuclear disaster destroyed 90 percent of homes in the small town of Futuba.[19] The government evacuated residents living within 20 km of the nuclear power plant, resulting in the displacement of 77,000 people.[20] Many people continue to live in temporary shelters and residences, uncertain if they would ever be able to return home.[21] In October 2012, the International Federation of Red Cross and Red Crescent Societies (IFRC) declared the Fukushima nuclear disaster to be an ongoing humanitarian crisis.[22]

Between countries, it has been documented that disaster-related deaths occur disproportionately in countries with low and medium levels of development.[23] The final report of the World Conference on Disaster Reduction noted that

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disasters in developing countries are compounded by increasing vulnerabilities related to changing demographics; technological and socio-economic conditions; unplanned urbanization; development within high-risk zones; under-development; environmental degradation; climate variability and climate change; geological hazards; competition for scarce resources; and the impact of epidemics such as HIV/AIDS. The report warns that this indicates a future in which disasters could "increasingly threaten" sustainable development of developing countries.[24]

Effects on specific MDGs

MDG 1: Eradicate extreme poverty and hunger

The effects of a nuclear weapon explosion on poverty and hunger would come directly from loss of human life; damage to housing and infrastructure; and the destruction of food and livestock resources.[25] In addition, farming, fishing, hunting, and food gathering activities would be devastated by the long-term effects of radiation. In the case of the meltdown at the Chernobyl nuclear power plant, the impact on agriculture was particularly severe. "Even where farming was still safe, stigma on produce from affected areas led to closure of markets for foodstuffs and produce from these areas."[26] The same was true of the Fukushima Dai-ichi disaster.

As demonstrated in the chapter on famine in this study, the use of nuclear weapons in a regional conflict would have significant effects on the climate, which would result in a decline in global agricultural output. This would be exacerbated by increases in food prices, making food inaccessible for hundreds of millions of the world's poorest populations. It would also increase malnutrition levels globally, and could result in panic and hoarding on an international level.

MDG 2: Achieve universal primary education

Disasters affect education because of the loss of life of students, their families, and educators; damage to schools and other related infrastructure; and disruption of classes. After a disaster, attending school is often lower on a family's list of priorities than rebuilding their lives. Some families are forced to migrate, which disrupts continuity in or access to education.[27]

In the wake of the March 2011 disaster at the Fukushima Dai-ichi Nuclear Power Station in Japan, the government undertook measures to decontaminate schools in Fukushima prefecture. However, Greenpeace argued the steps were "deplorably late and inadequate." A study by Greenpeace in August 2011 found that in samples from three schools outside of the 20km exclusion zone, average dose rates of radiation were above the maximum allowed under international standards, of 1 millisievert per year, or 0.11 microsievert per hour. Japan's education ministry established a looser standard, allowing up to 1 microsievert per hour of radiation in schools. While the government issued assurances that the schools were safe, many parents were not convinced.[28] When schools reopened, some more than a year after the disaster, attendance was typically low either because most of the residents had evacuated when the disaster occurred and had not yet returned, or because parents were concerned for their children's safety in the schools due to contamination of soil and food.[29]

In the instance of the use of a nuclear weapon in a populated area, the disruption to education services from damage to infrastructure, deaths of students and teachers, and fear of exposure to radiation would undoubtedly be much greater.

MDG 3: Promote gender equality and empower women

Gender disaggregated data on the impacts of disasters is not often available, which makes it difficult to study this aspect of development in relation to disasters. However, case studies suggest that women suffer disproportionately in disasters and that their specific needs are usually ignored during relief and rehabilitation initiatives.[30] Studies of the 2010 floods in Pakistan demonstrate that women were often overlooked in the distribution of relief and/or were unable to reach places where relief was being distributed due to social norms that restricted their mobility. Women usually take on the bulk of the post-disaster work of caring for the sick due to socially prescribed roles for women as primary caregivers. Dropout rates for girls in school typically increase and violence against women soars under the stress in post-disaster environments. There are also indicators demonstrating that many women and girls are trafficked or driven to prostitution after disasters.[31]

Health impacts unique to women may also be overlooked in the wake of a disaster. In 2012 the UN Special Rapporteur on the implications for human rights of the environmentally sound management and disposal of hazardous substances and wastes visited the Marshall Islands to assess the impact on human rights of the nuclear testing conducted in there by the United States from 1946 to 1958. He found that the full effects of radiation on Marshallese women may have been underestimated. Among other things, the bathing and eating habits of women potentially played a role in their higher rates of contamination. The Special Rapporteur found that women often bathed in contaminated water, which may have been overlooked as a possible means of exposure, as was the fact that women eat different parts of fish than men, such as bones and organ meat, in which certain radioactive isotopes tend to accumulate. The Special Rapporteur also notes, "Apparently, women were more exposed to radiation levels in coconut and other foods owing to their role in processing foods and weaving fiber to make sitting and sleeping mats, and handling materials used in housing construction, water collection, hygiene and food preparation, as well as in handicrafts."[32]

MDG 4: Reduce child mortality

Children face increased vulnerability in post-disaster situations. This is further exacerbated if the adult(s) they depend on for their well-being and survival are killed or go missing in the disaster. In addition, disasters result in increased limitations to accessing, developing, or sustaining support mechanisms that can provide necessary psychological, educational, protection and legal needs of children affected by disasters.[33]
A nuclear weapon explosion affects children in unique ways. In his report on nuclear testing in the Marshall Islands, the Special Rapporteur noted a high incidence of thyroid cancer in Marshallese children, due to the intake of iodine-131. This occurs "particularly through drinking milk contaminated with iodine, an element that accumulates in the thyroid, thereby inhibiting growth and the child's cognitive abilities, which could lead to mental disability."[34] Similar effects have been recorded in children in other irradiated environments, such as regions of Ukraine, Russia, and Belarus in the aftermath of the Chernobyl disaster.[35]

MDG 5: Improve maternal health

Pregnant women and young mothers are also highly vulnerable in disaster contexts. There is a higher risk of low-birth weight babies and infant deaths in disaster conditions, which can make delivering babies difficult and potentially life-threatening for the mother. Due to the destruction of crops, household food stocks, and livelihoods during a disaster, infants and pregnant and lactating women are increasingly vulnerable to malnutrition.[36]

In terms of effects from a nuclear explosion, studies on women's health in the aftermath of the Hiroshima and Nagasaki bombings, nuclear testing in Marshall Islands and in Kazakhstan, and the Chernobyl disaster provide useful though incomplete analyses of ways in which women are uniquely impacted by nuclear radioactivity. In particular, high rates of stillbirths, miscarriages, congenital birth defects, and reproductive problems (such as changes in menstrual cycles and the subsequent inability to conceive) have been recorded.[37] A possible link between breast cancer in younger women and women who were lactating at the time of exposure to nuclear radiation has also been found to exist.[38]

Women are uniquely impacted by nuclear radioactivity. In particular, high rates of stillbirths, miscarriages, congenital birth defects, and reproductive problems (such as changes in menstrual cycles and the subsequent inability to conceive) have been recorded.[37]

MDG 6: Combat HIV/AIDS, malaria, and other diseases

The effects of disasters on combating diseases vary greatly depending on location and type of disaster, but in general can cause damage to hospitals and medical infrastructure while creating conditions ripe for the spread of epidemics such as malaria, dengue, or diarrhea. HIV infection rates are observed to increase in the wake of a disaster, as men that migrate in search of work from disaster areas and are more likely to indulge in "high risk" sexual behaviour while poverty resulting from the disaster may force more women to engage in sex work.[39]

As discussed in the chapter on preparedness for dealing with the consequences of nuclear weapon use, the International Committee of the Red Cross has stated, "There is no effective international plan in place to assist the victims of nuclear weapons. The likely destruction of health infrastructure and widespread death and injury of health-care professionals in areas affected would increase human suffering exponentially."[40]

MDG 7: Ensure environmental sustainability

Disasters have devastating effects on the environment depending on their type, severity, and location. Generally, disasters affect key natural resources such as fields, soil, forests, and biodiversity. In the near term, restoring these assets is often impossible.[41] Nuclear weapons have a particularly horrific effect on the environment, from water to soil.

The effects of radiation on the human population are further exacerbated by "near-irreversible environmental contamination, leading to the loss of livelihoods and lands."[42] Decontamination and storage of radioactive materials following the use of a nuclear weapon is a complex, expensive, lengthy, and hazardous process. Nor are such processes necessarily successful. For example, the Special Rapporteur to the Marshall Islands expressed concern about a radioactive dump site on Runit Island; he was informed that "the structural integrity of the nuclear waste container is substandard, and that the hazardous radioactive materials contained could seep and leach into the marine and terrestrial environment."[43]

The radioactive fallout from the Chernobyl disaster contaminated large areas of Ukraine, Belarus, and Russia, "affecting life in rural communities for decades


Credit: UN Photo/ Martine Perret

to come." A report by UNDP and UNICEF notes, "Agriculture and forestry are forbidden in wide areas. Poverty forces many people to eat contaminated berries, mushrooms, game and fish, to feed contaminated hay to their cattle and to burn radioactively contaminated firewood in their stoves."[44]

MDG 8: Develop a global partnership for development

As noted above, in the wake of disasters, humanitarian aid is typically not increased but is rather shifted from regular development budgets, undermining the sustainability of global aid for development. Furthermore, countries are often obligated to repay aid granted in times of disasters. Indonesia, Sri Lanka, Thailand, and the Maldives are currently paying US$23.1 billion per year to donor countries and international financial institutions in debt repayment for tsunami relief.[45]

In the case of the use of a nuclear weapon, it is conceivable that the country targeted would not receive international aid, or if it did, would be required to pay it back. The cost of doing so could be crippling to national and local economies. In the case of a nuclear war with devastating regional and/or global effects, it would likely be highly unlikely for emergency aid to even be dispersed in a timely fashion if at all, as many countries would be struggling to deal with the various effects of the war. Furthermore, as noted above, a global economic recession would be likely to occur in the event of a nuclear exchange, which would dampen or eradicate economic growth in developing countries and interrupt rich countries' commitments to providing development aid.

Conclusion

This brief overview of the effects of disasters on poverty, hunger, and other aspects of development highlights that the humanitarian consequences of the use of nuclear weapons would have a particularly devastating impact on poor and vulnerable communities in both the immediate aftermath of the incident and the long-term. More comprehensive and scientific research would be necessary in order to determine what the specific effects of the use of nuclear weapons would be on development. However, this initial investigation illustrates that consequences would undermine efforts to achieve the MDGs and result in increased poverty, hunger, and mortality rates in developing countries.

The inadequacy of current mainstream development models coupled with the constant threat of the use of nuclear weapons derived from their very existence demands the reorganization and revitalization of both development and disarmament agendas. Nuclear disarmament should *serve as the leading edge of global demilitarization and redirection of resources to meet human needs and ensure environmental sustainability through an agenda in which development strategies are based on principles of economic justice and equality.*

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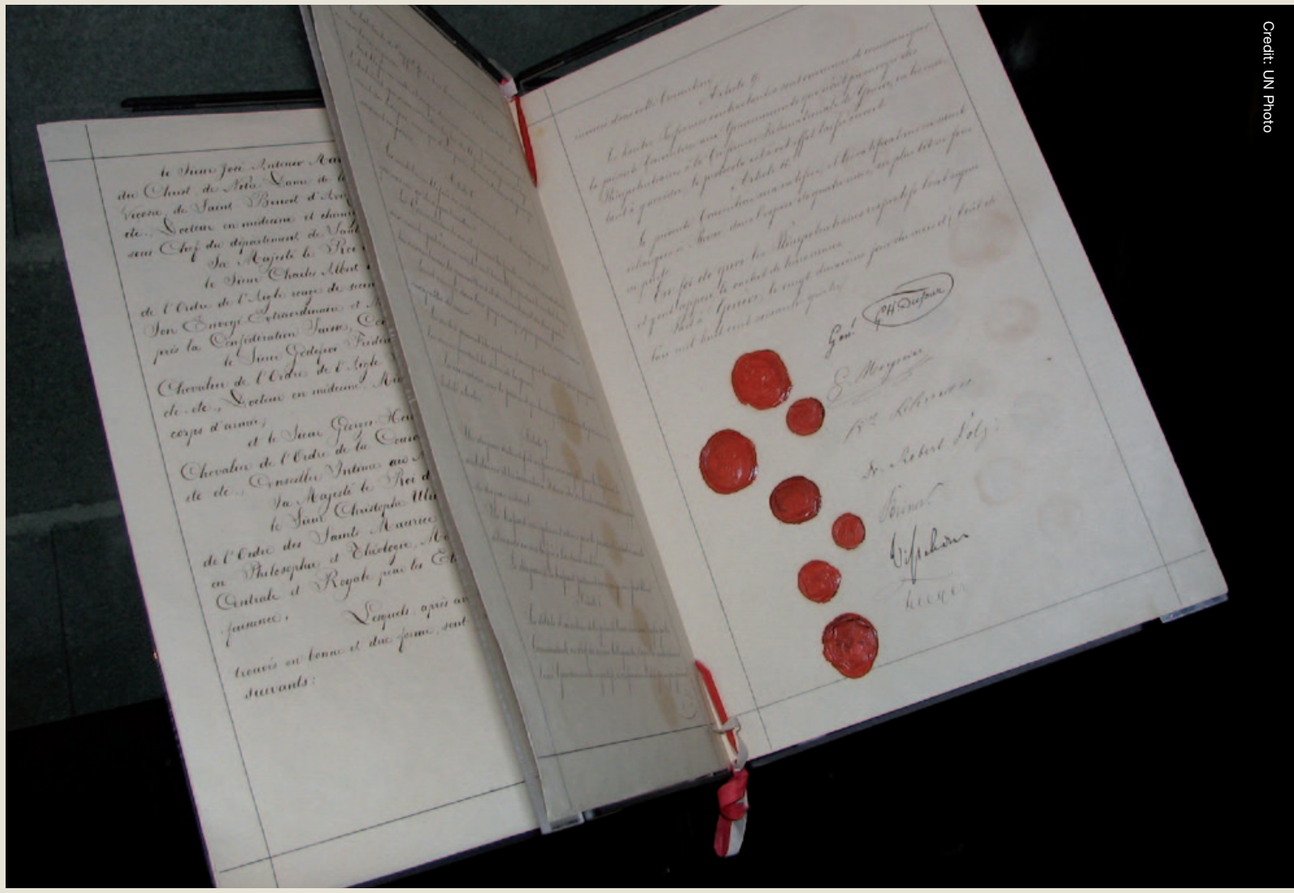
Law and order

Credit: Bigstock photo

International Humanitarian Law

Dr. John Burroughs

Credit: UN Photo/ John Isaac



Credit: UN Photo

The condemnation of the detonation of nuclear weapons in war as contrary to humanitarian values and law is as old as the nuclear age.[1] However, except for a brief period after World War II, that approach was a subsidiary theme in discourse about nuclear weapons, submerged by the power politics of rivalry between the United States and the Soviet Union. Now, with the Cold War long over, the success of humanitarian disarmament in adoption of the treaties banning anti-personnel landmines and cluster munitions, and the entrenchment of international humanitarian law as a global standard for assessing military operations, the humanitarian critique of reliance on nuclear weapons has surged to the forefront of the disarmament enterprise.

In May 2010, the five-year nuclear Non-Proliferation Treaty (NPT) Review Conference for the first time expressed "deep concern at the catastrophic humanitarian consequences of any use of nuclear weapons" and reaffirmed "the need for all states at all times to comply with applicable international law, including international humanitarian law."[2]

In November 2011, the Council of Delegates of the International Red Cross and Red Crescent Movement adopted a resolution whose first two operative provisions state that the Council:

> *1. emphasizes the incalculable human suffering that can be expected to result from any use of nuclear weapons, the lack of any adequate humanitarian response capacity and the absolute imperative to prevent such use,*
>
> *2. finds it difficult to envisage how any use of nuclear weapons could be compatible with the rules of international humanitarian law, in particular the rules of distinction, precaution and proportionality[.]*[3]

In October 2012, 34 United Nations (UN) member states, plus an observer state, the Holy See, made a "Joint Statement on the Humanitarian Dimension of Nuclear Disarmament" in the UN General Assembly's First Committee on Disarmament and International Security.[4] The Joint Statement *inter alia* says that "all rules of international humanitarian law apply fully to nuclear weapons, notably the rules of distinction, proportionality and precaution as well as the prohibition on causing superfluous injury or unnecessary suffering and the prohibition against causing widespread, severe and long-term damage to the environment." It then quotes the position on incompatibility of use of nuclear weapons with IHL set forth in the resolution of the Red Cross and Red Crescent Movement.

This chapter first introduces the body of law now known as international humanitarian law (IHL). It then explains the current state of IHL rules and principles particularly relevant to nuclear weapons, with a focus on those cited in the Red Cross/ Red Crescent resolution and the Joint Statement.

International humanitarian law – origins and purposes

Restraints on warfare go back thousands of years. In modern times, their codification in treaties was sparked by the Union Army's adoption of the Lieber Code during the US Civil War. Numerous treaties codifying rules have followed, notably the Hague treaties of 1899 and 1907, the 1949 Geneva Conventions, the 1977 Protocol I to the Geneva Conventions, and the 1998 Rome Statute of the International Criminal Court. The body of law has been known variously as the *jus in bello*, the law of war, the law of armed conflict, and more recently international humanitarian law.

The Geneva Conventions set forth rules protecting particular groups of non-combatants, prisoners of war, the wounded and shipwrecked, and civilians in occupied territories. Along with earlier treaty-mandated protections, this was known as international humanitarian law. Protocol I sets forth rules regulating methods and means of warfare, comprehensively codifying rules that had previously only been partially captured in the Hague and other treaties. Such rules traditionally had been considered part of the law of war or armed conflict. Gradually, however, due to the increased emphasis on the need to protect potential victims of warfare, the entire body of law, consisting both of rules like those protecting prisoners of war and those setting limits on the conduct of warfare, became known as international humanitarian law.

This nomenclature causes some cognitive dissonance. Rules on conduct of warfare generally *permit* the use of violence if necessary, proportionate, and discriminate, including civilian injury and death if considered proportionate to the military objective and within the bounds of discrimination. Nonetheless, the term "international humanitarian law" does convey the imperative of subjecting warfare to what the International Court of Justice (ICJ) called "elementary considerations of humanity" in its 1996 advisory opinion on nuclear weapons.[5]

The rules of IHL are rooted in treaty, custom, and general principles of law. They are set forth in multilateral treaties with wide participation of states and in military manuals on the law of armed conflict. The basic rules apply universally as a matter of customary international law and thus bind all states regardless of a state's adherence to a particular treaty. Rules of customary international law are based on a general and consistent practice of states accompanied by a sense of legal obligation. IHL rules apply equally to aggressor and defender states; thus IHL requirements are not lessened when a state uses force in self-defence.[6]

The purposes of IHL are to prevent cruelty and unnecessary suffering and destruction and to preserve the possibility of establishing a just and lasting peace. A 1997 US Navy publication states that the law of armed conflict

> *corresponds to the mutual interests of belligerents during conflict and constitutes a bridge for a new understanding after the end of the conflict. The law of armed conflict is intended to preclude purposeless, unnecessary destruction of life and property and to ensure that violence is used only to defeat the enemy's military forces. The law of armed conflict inhibits warfare from needlessly affecting persons or things of little military value. By preventing needless cruelty, the bitterness and hatred arising from armed conflict is lessened, and thus it is easier to restore an enduring peace.*[7]

The political philosopher John Rawls similarly held: "The aim of war is a just peace, and therefore the means employed must not destroy the possibility of peace and encourage contempt for human life that puts the safety of ourselves and of mankind in jeopardy."[8]

IHL rules particularly relevant to nuclear weapons

Distinction: Cited by the Red Cross/Red Crescent resolution, this principle requires that attacks distinguish between civilian personnel and objects, on the one hand, and combatants and other legitimate military targets, on the other. Attacks must not be directed against civilians or civilian objects, a bedrock rule codified in Protocol I and the Rome Statute.[9] The latter makes intentionally directing attacks against the civilian population or civilian objects a war crime for which individuals can be prosecuted.

Of great importance in the nuclear weapons context is the associated *prohibition of indiscriminate attacks*. An essential guide regarding this and other matters is a major International Committee of the Red Cross (ICRC) study first published in 2005, *Customary Humanitarian International Law*, principally authored by Jean-Marie Henckaerts and Louise Doswald-Beck.[10] The ICRC has a well-deserved reputation as the guardian of IHL. The study is an authoritative statement of the requirements of IHL. It identifies IHL rules and principles based upon exhaustive research into state practice and legal opinion as manifested by armed forces manuals on the law of armed conflict, multilateral treaties, including Protocol I and the Rome Statute, and other sources.

Drawing on Protocol I, the study states that indiscriminate attacks are defined as those:

> *(a) which are not directed at a specific military objective; (b) which employ a method or means of combat which cannot be directed at a specific military objective; or (c) which employ a method or means of combat the effects of which cannot be limited as required by international humanitarian law; and consequently, in each such case, are of a nature to strike military objectives and civilians or civilian objects without distinction.*[11]

Regarding violation of the requirement of limitation of effects, the study comments:

> *Practice in this respect points to weapons whose effects are uncontrollable in time and space and are likely to strike military objectives and civilians or civilian objects without distinction. The US Air Force Pamphlet gives the example of biological weapons. Even though biological weapons might be directed against military objectives, their very nature means that after being launched their effects escape from the control of the launcher and may strike both combatants and civilians and necessarily create a risk of excessive civilian casualties.*[12]

That compliance with the prohibition of indiscriminate attacks, as well as other IHL rules, requires the controllability of effects is recognized in US military manuals. Thus a 2007 Joint Chiefs of Staff publication states: "Attackers are required to only use those means and methods of attack that are discriminate in effect and can be *controlled*, as well as take precautions to minimize collateral injury to civilians and protected objects or locations."[13] Among protected objects and locations are cultural property and hospital and safety zones.[14] The inability to comply with the requirement of discrimination due to the uncontrollability of effects is the single most powerful argument for the unlawfulness of use of nuclear weapons.

Any nuclear explosion anywhere releases long-lived radiation whose dispersion cannot be controlled in either time or space.[15] Immense blast, heat, and immediate radiation effects are caused by a nuclear explosion and are devastating and highly lethal in an urban area. Moreover, several nuclear explosions, or a single large one, in an urban area, will create a very powerful firestorm. Nuclear explosions in numerous urban areas would generate soot and smoke that would circulate in the atmosphere on a scale causing global cooling and a subsequent decline in agricultural production. An electromagnetic pulse may also have deleterious effects on the operation of electronic equipment over a widespread area. In addition to violating the requirement of discrimination within the attacked state, the uncontrollable effects of nuclear explosions very likely will adversely affect neutral states, regionally and perhaps globally, violating the *law of neutrality*. Under that law, a part of the law of armed conflict but not usually considered part of IHL, the territory of neutral states is "inviolable."[16]

The principle of distinction, the associated prohibition of indiscriminate attacks, and the uncontrollable effects of nuclear weapons were central to the conclusion of at least general illegality of use of nuclear weapons reached by the International Court of Justice. The Court stated that a "fundamental" and "intransgressible" principle of IHL is that "States must never make civilians the object of attack and must consequently never use weapons that are incapable of distinguishing between civilian and military targets."[17] The Court also observed that the "destructive power of nuclear weapons cannot be contained in either space or time," citing in particular the "powerful and prolonged radiation" released by a nuclear explosion.[18] It found that in "view of the unique characteristics of nuclear weapons," their use "seems scarcely reconcilable with respect" for the prohibitions of methods and means of warfare "which would preclude any distinction between civilian and military targets, or which would result in unnecessary suffering to combatants."[19]

Proportionality: A second principle cited by the Red Cross/Red Crescent resolution requires that the collateral damage caused by an attack not be disproportionate to the expected military advantage. As formulated by the ICRC study, drawing on Protocol I:

> *Launching an attack which may be expected to cause incidental loss of civilian life, injury to civilians, damage to civilian objects, or a combination thereof, which would be excessive in relation to the concrete and direct military advantage anticipated, is prohibited.*[20]

The ICRC study separately finds that an identical requirement of proportionality applies to damage to the environment.[21] The ICJ also stated that impacts on the environment are to be taken into account in assessing whether an attack meets the requirement of proportionality.[22] The Rome Statute combines all factors to be considered in the following war crime:

> *Intentionally launching an attack in the knowledge that such attack will cause incidental loss of life or injury to civilians or damage to civilian objects or widespread, long-term and severe damage to the natural environment which would be clearly excessive in relation to the concrete and direct overall military advantage anticipated[.]*[23]

The requirement of proportionality in attack is to be distinguished from the requirements that a response to an armed attack as a matter of self-defence under Article 51 of the UN Charter be necessary and proportionate. The latter requirements go to whether any use of force is justified and if so, what scale of force is justified, under *jus ad bello*, the law regulating resort to force now primarily codified in the Charter. The ICJ stated that the risk of escalation is a factor to be taken into account in assessing proportionality as a condition of the exercise of self-defence.[24]

Proportionality in attack concerns operations aimed at achieving discrete military objectives in an ongoing armed conflict. Because it involves a balancing of costs and benefits, the requirement of proportionality in attack as such may not be understood to rule out all possible uses of nuclear weapons. This is true in particular when the target has a very high military value, as could be seen to be the case when an enemy is believed to be on verge of launching nuclear forces and it is believed that a preemptive attack can prevent or limit such a launch. Regardless of the considerations of law involved, this scenario demonstrates why the global elimination of nuclear weapons is imperative; the deployments themselves create completely unacceptable risks. From a legal standpoint, it remains the case that even if a proportionality calculus is believed to justify use of nuclear weapons, it is unlawful under the prohibition of indiscriminate attacks.

Precaution: The third principle cited by the Red Cross/Red Crescent resolution requires that measures be taken in advance to ensure compliance with the principles of distinction and proportionality. Drawing on Protocol I, the ICRC study states that "[a]ll feasible precautions must be taken to avoid, and in any event to minimise, incidental loss of civilian life, injury to civilians and damage to civilian objects."[25] One of several rules implementing this principle requires taking "all feasible precautions in the choice of means and methods of warfare."[26] The study separately sets forth the rule that "all feasible precautions must be taken to avoid, and in any event to minimise, incidental damage to the environment."[27]

The implications of the principle of precaution for the policy of 'nuclear deterrence' appear far-reaching. That policy involves in-depth planning and preparation for use of nuclear weapons in a broad range of scenarios. Decisions about use of nuclear weapons probably would be made rapidly under conditions of very high stress, precluding in-depth consideration of legal aspects.[28] Further, for at least Russia and the United States, deterrence involves constant readiness to launch nuclear forces rapidly, responsively or preemptively, in circumstances of an actual or anticipated nuclear attack by the other side.[29] The requirement of precaution would therefore seem to require in-depth consideration in advance, for typical scenarios, of compliance with the requirements of distinction and proportionality. However, as outlined above, such consideration, if fairly carried out, would lead to the conclusion that use would be unlawful and should not be executed or threatened. That in turn implies the imperative of urgent efforts to end reliance on nuclear weapons.

Damage to the environment: Cited by the Joint Statement, this rule is formulated by the ICRC study, drawing on Protocol I, as follows: "The use of methods or means of warfare that are

intended, or may be expected, to cause widespread, long-term and severe damage to the natural environment is prohibited."[30]

When included in Protocol I as negotiated in 1977, the rule was regarded as new, binding only states party to the treaty. The ICJ stated that the rule is a powerful constraint for state parties but did not determine whether it is customary international law.[31] On the basis of extensive adherence to Protocol I, military manuals on the law of armed conflict, and statements by governments in the context of conflicts, the ICRC study concluded that the rule now is customary, binding all states.[32] As noted above, damage to the environment is a factor to be taken into account in determining whether an attack meets the requirement of proportionality, including under the war crime defined in the Rome Statute. But the Protocol I prohibition is not subject to a test balancing collateral damage against military advantage. Moreover, violation of the prohibition does not depend on intent to cause damage or on the knowledge that it will do so, only on a hypothetical observer's reasonable expectation of that outcome.

The criteria for prohibited damage – widespread, long-term and severe – set a high threshold. But if any means of warfare can meet the criteria, nuclear weapons can; it is clear that many if not all nuclear explosions would contravene the prohibition. The ICRC study notes, without drawing a conclusion, that from the beginning the United States, United Kingdom, and France have sought to exclude the application of the rule to nuclear weapons.[33] The 35 states which endorsed the Joint Statement clearly consider the prohibition to apply to nuclear weapons. The statement pointedly says "*all* rules of international humanitarian law apply *fully* to nuclear weapons."[34]

Unnecessary suffering: Cited by the Joint Statement, this principle is formulated by the ICRC study, drawing on Protocol I, as follows: "The use of means and methods of warfare which are of a nature to cause superfluous injury or unnecessary suffering is prohibited."[35] The principle is understood to protect combatants. As stated by the ICJ, humanitarian law has prohibited certain weapons "either because of their indiscriminate effect on combatants and civilians or because of the *unnecessary suffering caused to combatants*, that is to say, a harm greater than that unavoidable to achieve legitimate military objectives."[36] In the modern era, the principle was first illustrated by the 1868 St. Petersburg Declaration which banned explosive bullets on the ground that they aggravate the suffering of already disabled soldiers. More recent examples are the treaty bans on **weapons that primarily injure by fragments not detectable by X-ray and on blinding laser weapons.37 The unnecessary suffering principle** is also cited along with the principle of distinction in the preamble of the treaty banning anti-personnel landmines.[38]
The protection of combatants against methods and means of warfare causing unnecessary suffering is an application of the broader principle of necessity, that the force applied in an attack may be no more than is required to achieve a military objective.[39] Under this principle, non-combatants and civilian infrastructure, as well as combatants, are protected against unnecessary death, injury and destruction. The principle of necessity is complemented by that of proportionality. If a military operation is necessary to achieve a military objective and no lesser application of force is available, the expected collateral damage may still be disproportionate to the military advantage to be gained and therefore unlawful.

Credit: Flickr/ Truthout.org

While not analyzing in any detail the application to nuclear weapons of the prohibition of causing unnecessary suffering, the ICJ cited it as one of the cardinal principles of IHL and relied upon it in concluding that use of nuclear weapons is at least generally illegal.[40] So far as the broader principle of necessity and the complementary principle of proportionality are concerned, given the uncontrollability of effects of nuclear explosions, a decision-maker cannot reasonably ensure compliance.[41]

Reprisals: Not specifically referred to in either the Red Cross/ Red Cross resolution or the Joint Statement is the question of reprisals. A reprisal during armed conflict is an otherwise unlawful action taken to induce the enemy to cease its unlawful actions. One element of nuclear deterrence is the threat of carrying out nuclear attacks in response to a prior nuclear attack. Indeed, the popular understanding tends to be that nuclear weapons are deployed only for this purpose. The reality is that use of nuclear weapons is contemplated in plans and doctrines in a wide range of circumstances, including in preemptive strikes. Further, after a nuclear attack, assuming there is a deliberative process, attempting by means of reprisals to induce the enemy to cease such attacks would likely be only one of several considerations in decision-making about whether and how to carry out a responsive use. Second use nuclear attacks may be rationalized on grounds other than reprisal, *e.g.* degrading the enemy's nuclear capabilities. Reprisals are criticized in military manuals on the law of armed conflict because they may cause escalation and may mask the unproductive and impermissible aim of vengeance.[42]

The legal status of nuclear reprisals is nonetheless important given the central role played by retaliatory deterrence in policy and even more so in popular understanding. Under universally binding law set forth in the 1949 Geneva Conventions, reprisals are prohibited against persons those Conventions protect, including prisoners of war and civilians in occupied territories. Protocol I sets forth additional restrictions on reprisals, against civilian populations of enemy states, civilian objects in general, works and installations containing dangerous forces, and the environment, among other categories. However, it is not crystal clear that the Protocol I restrictions are universally binding law in part due to positions taken by the Western nuclear weapon states.

One can imagine an attempt to justify as a reprisal the second use of nuclear weapons against military targets in non-urban areas. But at its core, retaliatory deterrence contemplates reprisals inevitably harming civilian populations. Protocol I provides: "Attacks against the civilian population or civilians by way of reprisals are prohibited."[43] The ICRC study states that "there appears, at a minimum, to exist a trend in favour" of considering that prohibition to be universally binding.[44] The study notes, among other things, decisions of the International Criminal Tribunal for the Former Yugoslavia recognizing such a prohibition, based largely on the imperatives of humanity and public conscience.[45] In general, from IHL to the Rome Statute to human rights law, the principle of the immunity of civilians to attack has become more and more entrenched in the post-World War II period.

The ICJ declined to pass expressly on the legality of reprisals using nuclear weapons, other than noting that they are subject to the requirement of proportionality also applicable to the use of force in self-defence.[46] However, elsewhere in the opinion, the Court states the principle of immunity of civilians to attack in categorical fashion: "States must *never* make civilians the object of attack."[47] The 2011 Vancouver Declaration, initiated by civil society groups and signed by numerous eminent international lawyers including former judges of the ICJ, states:

> *Use of nuclear weapons in response to a prior nuclear attack cannot be justified as a reprisal. The immunity of non-combatants to attack in all circumstances is codified in widely ratified Geneva treaty law and in the Rome Statute of the International Criminal Court, which provides inter alia that an attack directed against a civilian population is a crime against humanity.*[48]

Conclusion

Based on the requirements identified in the Red Cross/ Red Crescent resolution and the Joint Statement relating to distinction, proportionality, precaution, damage to the environment, and unnecessary suffering, the case is overwhelming that the use of nuclear weapons contemplated in the plans and doctrines of states possessing nuclear arsenals would violate international humanitarian law. That is a powerful reason for continuing the practice of non-use of nuclear weapons since World War II. It further demonstrates the urgent need to ban any use whatever of nuclear weapons, thus confirming the existing illegality of use; to ban their possession; and to provide for their verified and irreversible elimination. *Banning and eliminating nuclear weapons would uphold the rule of law and advance the purposes of international humanitarian law of protecting life and making possible a civilized and enduring peace.*

Credit: UN Photo/ Eskinder Debebe

Notes:

1 Thus in 1950, the ICRC noted the rule pre-existing the nuclear age requiring discrimination between combatants and non-combatants and stated that with "atomic bombs and non-directed missiles, discrimination became impossible. Such arms will not spare hospitals, prisoner of war camps and civilians. Their inevitable consequence is extermination, pure and simple." Quoted in "Bringing the era of nuclear weapons to an end," Statement of Jacob Kallenberger, President of the ICRC, Geneva, 20 April 2010, http://www.icrc.org/web/eng/siteeng0.nsf/html/nuclear-weapons-statement-200410. In 1961, UN General Assembly Resolution 1653 declared that the "use of nuclear and thermo-nuclear weapons would exceed even the scope of war and cause indiscriminate suffering and destruction to mankind and civilization and, as such, is contrary to the rules of international law and to the laws of humanity." Adopted by a vote of 55 to 20, with 26 abstentions; the negative votes largely came from the Western nuclear weapon states and their allies. For more on the history of the humanitarian critique of nuclear weapons, see J. Burroughs, *The Humanitarian Imperative for Nuclear Disarmament* (2010), Middle Powers Initiative Briefing Paper, pp.5-7:http://www.middlepowers.org/pubs/Geneva_2010_Briefing_Paper.pdf

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8 J.Rawls, *A Theory of Justice* (1971), Belknap Press of Harvard University Press, pp. 378-379.

9 Protocol I, Article 51(2) and Article 52(1); Rome Statute, Article 8(2)(b)(i) and (ii).

10 J.M. Henckaerts,and L. Doswald-Beck, *Customary Humanitarian International Law (2009),* Vol. I, Rules, International Committee of the Red Cross, Cambridge University Press; http://www.icrc.org/eng/resources/documents/publication/pcustom.htm.

11 Ibid. at p. 40.

12 Ibid. at p. 43.

13 US Joint Chiefs of Staff, Joint Pub. No. 3-60, *Joint Targeting* (2007) E-2 (emphasis supplied), quoted in Moxley, Burroughs, and Granoff, p. 621.

14 Henckaerts and Doswald-Beck, op. cit., p. 119 and 127.

15 This feature of nuclear weapons may serve to establish the illegality of their use in various marginal situations, *e.g.* underwater or in a remote location. Also relevant to the assessment of lawfulness in such circumstances is the risk of escalation. In any case, the issue of lawfulness of use in marginal situations is a diversion from the issue of the lawfulness of typical uses contemplated in the plans and doctrines of states possessing nuclear arsenals. See: Moxley, Burroughs, and Granoff, pp. 660-661, 672.

16 1907 Hague Convention (V) Respecting the Rights and Duties of Neutral Powers and Persons in Case of War on Land, Article 1. Cf. Nuclear Weapons Advisory Opinion, paragraph 88-89.

17 Ibid. at paragraphs 78- 79.

18 Ibid. at paragraph 35.

19 Ibid. at paragraph 95. As this finding indicates, the thrust of the entire opinion is that the use of nuclear weapons would violate international law, in particular IHL, and the Court formally concluded that threat or use of nuclear weapons would "generally be contrary" to international law. Ibid. at paragraph 105(2) E. However, the Court went on to state that in view of the "present state of international law as a whole" and the "elements of fact at its disposal," it could not reach a "definitive" conclusion regarding the lawfulness or unlawfulness of threat or use of nuclear weapons in an "extreme circumstance of self-defence, in which the very survival of a State is at stake." Ibid. This gap in the opinion probably reflects in part the fact that the Court was called upon to assess the lawfulness of "threat" as well as "use" of nuclear weapons, thus implicating nuclear deterrence, which was vehemently defended by the nuclear weapons states, as well as specific threats, as opposed to uses, made in extraordinary circumstances. Regarding the legal status of nuclear threats and deterrence, See: Moxley, Burroughs, and Granoff, pp. 675- 678.

20 Henckaerts and Doswald-Beck, op. cit., p. 46.

21 Ibid. at p. 143.

22 Nuclear Weapons Advisory Opinion, paragraph 30.

23 Article 8(2)(b)(iv).

24 Nuclear Weapons Advisory Opinion, paragraph 43.

25 Henckaerts and Doswald-Beck, op. cit., p. 51.

26 Ibid. at p. 56.

27 Ibid. at p. 147.

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29 See generally H.Kristensen and M. McKenzie, *Reducing Alert Rates of Nuclear Weapons* (2012), United Nationa Institute for Disarmament research: http://mercury.ethz.ch/serviceengine/Files/ISN/154017/ipublicationdocument_singledocument/ef8af002-8a1b-4263-b24c-340467240f74/en/pdf-1-92-9045-012-M-en.pdf .

30 Henckaerts and Doswald-Beck, op. cit., p. 151.

31 Nuclear Weapons Advisory Opinion, paragraph 31.

32 Henckaerts and Doswald-Beck, op. cit., p. 152-155. A treaty reinforcing the prohibition is the Convention on the Prohibition of Military or Any Hostile Use of Environmental Modification Techniques. A broader supportive trend is the emergence of the concept of "ecocide." See: ibid. at pp. 153, 155-156; see: also P.Higgins, *Eradicating Ecocide: Laws and Governance to Stop the Destruction of the Planet* (Shepheard-Walwyn, 2010), and www.eradicatingecocide.com.

33 Henckaerts and Doswald-Beck, op. cit., p. 153-155.

34 Emphasis supplied.

35 Henckaerts and Doswald-Beck, op. cit., p . 237.

36 Nuclear Weapons Advisory Opinion, paragraph 78 (emphasis supplied).

37 1980 Protocol on Non-Detectable Fragments; 1995 Protocol on Blinding Laser Weapons. Both are protocols to the 1980 Convention on Prohibitions or Restrictions on the Use of Certain Conventional Weapons Which May be Deemed to be Excessively Injurious or to Have Indiscriminate Effects.

38 1997 Convention on the Prohibition of the Use, Stockpiling, Production and Transfer of Anti-Personnel Mines and on their Destruction.

39 See: Moxley, Burroughs, and Granoff, pp. 617-620.

40 Nuclear Weapons Advisory Opinion, paragraph s 78, 95, 105(2)E. See also Moxley, Burroughs, and Granoff at pp. 620-621 and 651-653.

41 See *ibid*. at pp. 621-624.

42 See *ibid*. at pp. 626-627.

43 Article 51(6).

44 Henckaerts and Doswald-Beck, op. cit., p. 520-523, quotation at p. 523.

45 *Ibid*. at p. 523. The Martens Clause set forth in Protocol I, Article 1(2), makes "principles of humanity" and the "dictates of the public conscience" factors in determining the law protecting civilians and combatants.

46 Nuclear Weapons Advisory Opinion, paragraph 46.

47 Ibid, paragraph 78 (emphasis supplied).

48 *Law's Imperative for the Urgent Achievement of a Nuclear-Weapon-Free World* (2011),, 11 February 2011, http://www.lcnp.org/wcourt/Feb2011VancouverConference/vancouverdeclaration.pdf. For background, commentary, and a list of eminent signatories, see J.Burroughs, *The Vancouver Declaration and the Humanitarian Imperative for Nuclear Disarmamen* (2011)t, Nuclear Abolition Forum, no. 1 http://www.abolitionforum.org/site/wp-content/uploads/2012/01/NAF-First-issue.online-version.pdf

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The unknown known

Magnus Løvold

Are the humanitarian consequences of a nuclear detonation simply too dire to prepare for?

"Denial is not just a river in Egypt", the American author and humourist Mark Twain said in a lucid moment. Indeed, the phenomenon, oftentimes referred to as "abnegation" by psychologists like Sigmund Freud and his acolytes, has been identified as a common psychological defence mechanism, in which a person is faced with a fact that is too uncomfortable to accept and rejects it instead, insisting that it is not true despite what may be overwhelming evidence.

Denial might have certain short-term benefits, such as preventing a person from having to acknowledge painful thoughts and helping them maintain their worldview from an unacceptable reality. In the long-term, however, psychology teaches us that denial leads to a distortion of language and logic, a deterioration of problem solving and decision making, and eventually a complete abandonment of cognitive strategies and rational arguments.

As such, the recent shift in the intergovernmental discourse on nuclear weapons towards a greater focus on the humanitarian impact these weapons cause, might prove to be an uncomfortable experience for many. For a long time, the dominant nuclear weapons discourse has revolved around questions of deterrence, the risk of proliferation, and more recently, nuclear terrorism. As if to avoid having to be reminded of the horrific nature of these weapons, the discourse has taken place at an unusually high level of theoretical abstraction, and a long list of acronyms—such as MAD, PTBT, NPT, INF, SALT I and II, FMCT, CTBT and New START. It has constituted something resembling a tribal language, which for the uninitiated, of course, appears as downright gibberish. But beneath the smokescreen of incomprehensible acronyms and numbers, resides a long series of uncomfortable and hitherto unanswered questions about the all too real effects any use of these weapons have.

One of the questions that has the potential to spark a significant level of controversy, finger-pointing, confusion and disclaimers, is the extent to which anyone is prepared to mount a humanitarian response to the effects of a nuclear detonation. Almost seventy years have passed since the world stood witness to the catastrophic humanitarian impact of the nuclear bombings of the Japanese cities of Hiroshima and Nagasaki, and yet, as Dominique Loye and Robin Coupland from the International Committee of the Red Cross (ICRC) concluded in an article published in 2007, "no government, international organization (including the ICRC and other components of the International Red Cross and Red Crescent movement), non-governmental organization or collaborative body has either realistic plans or the capacity to mount [an effective international assistance response]" in the event of a nuclear detonation.[1]

As if to avoid having to be reminded of the horrific nature of these weapons, the discourse has taken place at an unusually high level of theoretical abstraction, and a long list of acronyms—such as MAD, PTBT, NPT, INF, SALT I and II, FMCT, CTBT and New START.

Response ability?

As shown in the previous sections of this publication, the initial flash, the radiation, blast, and the ensuing firestorms and fallout of a nuclear detonation in a populated area would almost certainly lead to a catastrophic humanitarian disaster. Indeed, the bombing of Hiroshima and Nagasaki in 1945 have already demonstrated the almost incomprehensible scale of such an event. More recent studies, such as M.V. Ramana's hypothetical case-study of the effects of a nuclear blast over the Indian city of Mumbai,[2] clearly indicates that a nuclear detonation would lead to what is known in the humanitarian community as a 'complex emergency'.[3]

The capacity to assist survivors of a nuclear detonation would first and foremost be restricted by limited access to the victims. As shown in the 2007 City of Hiroshima 'Report from the Committee of Experts on Damage Scenarios Resulting from a Nuclear Weapons Attack',[4] any intervening agency would have to find a way to access the area affected without exposing themselves to unacceptable levels of radiation, particularly during the days immediately after the explosion. The breakdown of electric power systems and the destruction of telecommunication infrastructures caused by the electromagnetic pulse of such an event would moreover make information gathering, coordination of effective command structures, and communication with victims extremely challenging. The firestorms erupting a few minutes after the explosion would pose another barrier, and fire fighting would itself be almost impossible due to the combination of hurricane-force winds, thick smoke, the destruction of water mains, and the presence of debris from the blast blocking roads and access routes.[5]

If, however, intervening agencies should manage to obtain access to victims, medical assistance would most likely be severely restricted by the destruction of medical infrastructure such as hospitals and pharmacies. According to a 1987 report from the World Health Organization, the bombing of Hiroshima left 42 of 45 of the city's hospitals non-functional.[6] It also killed 90 percent of the doctors, 92 percent of the nurses, and 80 percent of the city's pharmacists. A recent paper by Frank Boulton also draws attention to the likely disruption of blood transfusion services in the wake of the humanitarian and health crisis following multiple detonations of nuclear weapons.[7] Obviously, mounting an effective humanitarian response without access to basic medical infrastructure, is fraught with difficulties.

The momentous obstacles facing any humanitarian response to a nuclear detonation have led many to conclude that such a response is not only challenging to mount, but impossible. Indeed, that was the conclusion of the 2006 report from the Hiroshima Committee of Experts, and the 1987 report from the

Credit: UN Photo/ Martine Perret

Credit: Pond5/ Gemenacom

"Every agency involved, even at the national level in wealthy countries, would admit that their capacity would be inadequate".[13]

World Health Organization. And the International Physicians for the Prevention of Nuclear War (IPPNW) has for many years highlighted the lack of correspondence between existing civil defence programmes against nuclear explosions and the actual medical effects of such an event, and argued that the only appropriate "response" to nuclear weapons is abolition.

International humanitarian response

This commendable inference notwithstanding, the ICRC's conclusion that there does not seem to exist any realistic plan for responding to the humanitarian impact of a nuclear detonation might cause surprise. After all, there are still around 19,000 nuclear weapons in the world, and approximately 2,000 of these are on high alert status, ready to be launched within minutes. In such a situation, and with knowledge of several nuclear near-accidents, one would think that *someone* had come up with a humanitarian response plan, especially given the increase prominence and importance of humanitarian issues in the post-Cold War era.

After the Swiss businessman Jean-Henri Dunant witnessed the now famous Battle of Solferino in northern Italy in 1859, he decided, to set up an International Committee for Relief to the Wounded[8] due to the suffering of wounded soldiers and the near total lack of medical attendance and basic care. Since then, the number, scope, and importance of international and national, governmental, intergovernmental and non-governmental humanitarian organisations has increased with a steady pace. In the post-Cold War era, moreover, this development seems to have intensified. To cite one of many indicators of this development, the Active Learning Network for Accountability and Performance (ALNAP), a sector-wide network made up of key international humanitarian organisations and experts, has estimated that the humanitarian fieldworker population has increased by approximately six per cent per year over the past 10 years.

As a consequence of this development, international humanitarian response plans now exist for almost any disaster. The International Federation of Red Cross and Red Crescent Societies (IFRC), a humanitarian movement counting nearly 100 million volunteers worldwide, have response plans for everything from natural disasters such as earthquakes, landslides, tsunamis, volcanoes, avalanches, floods, heath waves, droughts, wildfires, cyclones, storms and wave surges, disease epidemics and insect/animal plagues, to technological or man-made disasters such as conflicts, famine, displaced populations, industrial accidents and transport accidents.[9]

To take one recent example, the 'Humanitarian Response Plan 2012'[10] for Yemen, published by the United Nations Children's Fund (UNICEF), contains detailed information of both most-likely and worst-case scenarios; a comprehensive overview of the expected humanitarian consequences; an assessment of humanitarian needs and concrete plans for how to respond to these scenarios in a well-coordinated and efficient way; as well as a range of measureable success criteria. Among a large range of identified needs, the report stipulates that there is a growing need for essential non-food items (NFIs) "including mattresses, blankets, kitchen sets, stoves, buckets and hygiene materials" for internally displaced persons (IDPs) living inside and outside camps.[11] If you start asking questions about any of the abovementioned humanitarian disasters, somewhere down the line you are bound to find an organisation that who is eager to present its plan for how to respond.

A black swan?

Despite general improvements in the international community's capacity to respond effectively to major disasters, however, this does not seem to have increased the international preparedness situation when it comes to responding to a nuclear detonation. Even at the national level, government agencies responsible for civil protection and emergency management do not seem to have developed any coherent plan for how to respond to such an event. The Federal Emergency Management Agency (FEMA), the agency responsible for coordinating disasters in the United States, has published some general advice for what to do in the event of a nuclear blast. However, as pointed out by Patrick J. Massey in his thesis on the emergency management community's ability to respond to a nuclear or radiological weapons attack, "there are no training courses or outreach materials on responding to large-scale radiological emergencies geared specifically towards the local emergency manager," although the local emergency manager will be the primary coordinator or the response operation.[12] According to Peter Herby, former head of ICRC's arms section, "every agency involved, even at the national level in wealthy countries, would admit that their capacity would be inadequate".[13] This is in spite of the fact that the humanitarian impact of a nuclear detonation, if not being subject to any systematic scientific scrutiny, has historically been experienced on two occasions. Numerous reports from non-governmental organisations such as the International Physicians for the Prevention of Nuclear War (IPPNW) have also established that the blast, firestorms, prompt radiation and radioactive fallout of a nuclear detonation would produce a large-scale humanitarian disaster.[14] So why, one might ask, has no such plan been put in place? There appears to be a sense of collective defeatism—a sense of collective abnegation.

According to René Nijenhuis, Humanitarian Affairs Officer at the UN Office for the Coordination for Humanitarian Affairs (OCHA), the reason why no such plan has been put in place is that a nuclear detonation has been thought of as a so-called 'Black Swan event'. The Black Swan theory was developed by Nassim Nicholas Taleb in 2004, to describe an event that is a surprise to the observer, has a major impact, and after the fact is often inappropriately rationalised with the benefit of hindsight.[15] "You cannot rationalise what you haven't experienced,"[16] Mr. Nijenhuis says, suggesting that the reason why there is no plan for international assistance in the event of a nuclear weapons detonation is that such an event would be a "a thing we do not know we don't know", or an unknown unknown—the term coined by former US Secretary of Defence

Donald Rumsfeld to address the absence of evidence linking the government of Iraq with the supply of weapons of mass destruction to terrorist groups. Given the low probability of a nuclear detonation, Mr. Nijenhuis argues,

> The question many countries ask themselves is whether they *should* be prepared for such an event. It is very unlikely, so we cannot, we will not, prepare for this. It is true that we generally know too little about the scale of the effects of a nuclear detonation, particularly what concerns the effects of nuclear radiation, and the operational details in such an event would be extremely challenging to sort out. But that doesn't necessarily mean we are not prepared. If there was a nuclear detonation somewhere in the world, the humanitarian community would kick into gear, somehow.[17]

It is a common, and of course not wholly unjustified, act for international organisations to pass uncomfortable questions on to their member states. And it may very well be true that the reason why there is no international response plan for a nuclear detonation is that governments consider such an event to be so unlikely that they decide to put their money into other, presumably more urgent, humanitarian preparedness programmes. Indeed, as Peter Herby asks rhetorically: "Does the world really want to invest in the capacity to respond adequately, or even better, to the use of nuclear weapons? Is that what we should be investing in?"[18]

This, however, does not explain why the governments do not see this as a priority in the first place. Because the truth of the matter is that a nuclear detonation is no 'black swan'—no unknown unknown. It is nearly impossible to predict with any precision or certainty the exact scope of the calamity that would result from the use of nuclear weapons, and we cannot know when or where the next detonation of a nuclear weapon will take place. Yet the very existence of nuclear weapons and the continuing threat these weapons pose to all life on earth is well known and beyond contestation. And it is rather surprising to see how often it seems to be forgotten that nuclear weapons have actually been used twice against civilians. The international community have already been warned about the catastrophic humanitarian effects of these weapons. Still, with 19,000 nuclear weapons in the world, the threat of another nuclear catastrophe is looming large

The unknown known

Unexpected events of large magnitude and consequences have played, and continue to play, a decisive role in history. They can change the demographics of a country, define generations, trigger wars, overturn governments, and, in some cases, help presidential candidates win elections. Given the sheer scale of the effects of a nuclear detonation, it is therefore somewhat surprising to see that neither international organisations nor governments seem to be more concerned about preparing for such an event— or better yet, ensuring that the cause of such an event, the very existence of nuclear weapons, is eliminated.

The reason why there are no realistic plans for how to mount an effective international assistance response to a nuclear detonation is not because such an event is an unknown unknown but because it is what the psychoanalytic philosopher Slavoj Zizek has called an 'unknown known', i.e. something we intentionally refuse to acknowledge that we know. We do this because it would be too uncomfortable to acknowledge that the humanitarian effects of such an event would be extremely challenging, if not impossible, to respond to. Instead of accepting the catastrophic historical reality of Hiroshima and Nagasaki, we seem to have resorted to denial, distorting our language and logic along the way. We have refused to acknowledge the effects that these weapons have on human beings and the environment, and engaged instead in a discussion about incomprehensible acronyms and abstract theories of strategic stability. And from this perspective, the absence of an international plan of assistance in the event of a nuclear detonation is perhaps not so much a result of a rational risk assessment as a result of our collective inability to grasp the magnitude and scope of the effects of such an event.

Credit: UN Photo/ Tim McKulka

Notes:

1 D. Loyeand R. Coupland, *Who will assist the victims of use of nuclear, radiological, biological or chemical weapons - and how?* (2007), International Review of the Red Cross, No. 866

2 M.V. Ramana, *The South Asian Bomb: Effects of a Nuclear Blast Over Bombay* (1998), Medicine and Global Survival, Vol. 5, No. 2, pp. 74-77

3 Complex emergencies have been defined by the World Health Organization (WHO) as "situations of disrupted livelihoods and threats to life produced by warfare, civil disturbance and large-scale movements of people, in which any emergency response has to be conducted in a difficult political and security environment." See: http://www.who.int/environmental_health_emergencies/complex_emergencies/en/ for details.

4 See http://ippnweupdate.files.wordpress.com/2012/11/houkokue1.pdf

5 M.V. Ramana (1998), op. cit., p. 75

6 *Nuclear Weapons: a unique threat to humanity* (2011), Australian Red Cross, International humanitarian law magazine issue 2: http://www.redcross.org.au/files/IHLnuclear.pdf

7 F. Boulton , *Blood Transfusion Services in the wake of the humanitarian and health crisis following multiple detonations of nuclear weapons* (2012), unpublished

8 Renamed "International Committee of the Red Cross in 1876."

9 See: http://www.ifrc.org/en/what-we-do/disaster-management/ for details.

10 See: https://docs.unocha.org/sites/dms/CAP/2012_Yemen_HRP.pdf

11 Ibid., pp. 81

12 P.J. Massey, *Forging a framework to improve the emergency management community's ability to respond to a nuclear or radiological weapons attack* (2007), Naval Postgraduate School California, Monterey

13 Interview with Peter Herby, January 11, 2013.

14 M.V. Ramana, Bombing Bombay, (1999), International Physicians for the Prevention of Nuclear War; http://www.ippnw.org/pdf/Bombay.pdf

15 See: N.N. Taleb, *The Black Swan: The Impact of the Highly Improbable* (2007), New York Times, April 22, 2007

16 Interview with René Nijenhuis, December 11, 2013

17 Ibid.

18 Interview with Peter Herby, January 11, 2013.

Carol Bolken and her Grandfather, Mejatto, 1985. Carol is one of the severely deformed children born on Rongelap. Because Carol's mother was not on Rongelap during the Bravo test, but moved back to be with her family in 1957, she was considered "unexposed." Carol's congenital conditions are not an acknowledged and compensable radiation-related injury. Credit: Greenpeace/ Fernando Pereira.

Case studies

Use of atomic bomb in war: Hiroshima and Nagasaki

Dr. Masao Tomonaga

Preface

On 6 and 9 August 1945, near the end of the World War II, the United States detonated two atomic bombs 500 meters above two mid-sized Japanese cities, Hiroshima and Nagasaki. The nuclear era thus began. Under the gigantic mushroom clouds, 280,000 citizens in Hiroshima and 240,000 citizens in Nagasaki were thrown into agony. 140,000 in Hiroshima and 73,000 in Nagasaki died instantaneously or within three months due to combined injuries by blast wind, radiant heat and ionizing radiation.

A figure of death rates calculated in the aftermath was exactly concentric: almost 100% within 500 meters from the Ground Zero; 90% within 750 meters; 70% within 1000 meters; 50% within 1250 meters; and 30% within 1500 meters. The concentric circles of death rates in both cities precisely overlapped as if two scientific experiments were repeated1).

Those dead citizens were mostly civilians, including many children. In the proximity of ground zero, human bodies were burned and carbonized by 2000˚C of heat ray. At the same time they were squeezed by blast wind with speeds over 80 meters/second and irradiated by more than 100 Gray (Gy) of gamma and neutron rays. It is possible to say that they were killed in three ways simultaneously, as reported by the research team of the British Navy.

Major components of the energy generated by the atomic bombs consisted of blast wind (50%), radiant heat (35%), and radiation (15%). Only thick concrete buildings provided effective shielding against radiation. 50% of the exposed died at a radiation dose of around 4 to 5 Gy.

Many of those who survived the immediate blast of the atomic bombs at various points were severely injured by debris and glass pieces from broken houses and at the same time had skin burns due to heat rays and/or fire. Any meaningful medical aid by rescue teams or hospitals was unavailable because of the total destruction of city infrastructure. At Nagasaki Medical College Hospital, the largest and strongest concrete building in Nagasaki, located at 600 meters from the Ground Zero, did provide good shielding. Despite this, 900 lives were lost, about half of the total number of doctors, nurses, and medical students and hospital function completely collapsed.

140,000 in Hiroshima and 73,000 in Nagasaki died instantaneously or within three months due to combined injuries by blast wind, radiant heat and ionizing radiation

Immediate effects of blast wind and radiant heat

For many victims of the atomic bomb, the heat rays destroyed entire layers of skin and subsequently the skin began to tear off, causing severe pain and massive exudation of blood serum, subsequently causing a severe dehydration. The survivors suffered strong thirst and many drank river water, but their intestines could not absorb the water efficiently due to massive erosive destruction of the mucous membrane caused by the large amount of radiation. Injuries due to debris and glass further gave survivors pain and wounds became infected, often leading to fatalities.[1)]

Immediate effect of ionizing radiation

The first sign of radiation injury to the body was hair loss on the head. Many people who were exposed within 2 km showed this within two to three weeks. The radiation also destroyed bone marrow where blood cells are normally produced. Within a week, blood cell numbers began to decline steeply and the production of white cells, which are essential for body defense against bacteria, was interrupted. Decrease or absence of white cells also aggravated skin infections. No medical care, such as antibiotics and drip infusion of water and electrolytes were available. Only a few lucky survivors could overcome this agonizing period and recover their health. Eventually, about half of the survivors within 1.5 km died within three months after the bombings.[1]

> “Human bodies were burned and carbonized, squeezed by blast wind, and irradiated of gamma and neutron rays. They were killed in three ways simultaneously.”

Late effect of atomic bomb radiation

About 250,000 people of Hiroshima and Nagasaki finally recovered their health. City regeneration process started, but very slowly due to the collapsed economy and scarcity in human resources in a confused society just after the end (15 August) of the war. They inevitably started their new daily lives with a serious shortage of food and living goods. After spending three years of regeneration, the atomic bomb survivors, called Hibakusha in Japanese, met the first signs of late health effects of atomic bomb irradiation: an insidious onset of a radiation-induced malignant disease, leukemia.

1) Leukemias

In 1948, doctors both in Hiroshima and Nagasaki began to recognize a gradual increase of the number of leukemia patients, including children. The excess rate of leukemia continued to elevate until 1955. Both acute and chronic types of leukemia were observed. These leukemias were later analysed in detail when dose estimation became available in 1965. A clear radiation-dose dependency was obtained as a curve, which increased exponentially above 100 mSv (around 2 km from the Ground Zero). Total leukemia incidence was four to five times higher than amongst control population who were not exposed to radiation. Around 1955-60, ten to fifteen years after the bombings, the excess rate of leukemia reached the peak and gradually declined by 1970. However, even 67 years after the bombings, the number of cases of leukemia is still slightly higher among proximally irradiated survivors than distant (2-8km) survivors.[2]

Moreover, recent epidemiological studies clearly elucidated a four times higher risk of a special type of leukemia, called myelodysplastic syndromes (MDS).[3] Those children under the age of 10 at the time of bombings are now suffering from this increase of MDS. MDS occurs typically amongst elderly people of the general population. The atomic bomb-affected children are now passing into their seventies. The increase of MDS among childhood survivors indicates that in 1945 the massive irradiation of the body injured DNA containing important genes for cell function. Such DNA-injured cells continued to live for several decades and finally gained more gene abnormalities to become full leukemia cells.

2) Cancers

While recorded cases of leukemia were declining in the 1960s, solid cancer incidences started to elevate insidiously. The cancer incidence persisted for a long time and reached a peak around 2000. The plateau continues now in 2012. Cancer types are lung, breast, thyroid, stomach, colon, liver, skin, urinary bladder, and so on. The excess of these cancers was also clearly dependent on the total dose (gamma + neutron) of radiation the survivors received. Again, 100 mSv was the lowest dose, which gave a significant increase in cancer incidence.

Recent epidemiological studies also showed a dose-dependent increase of multiple cancers in individual survivors exposed in short distance (within 2km). The multiple cancers are independent primary cancers occurring in different organs and not metastasis of an original cancer. Some survivors suffered from three or more cancers during the period of 20 years. Because a survivor's body was generally exposed to radiation, involving all organs, multiple cancers seems a reasonable consequence. Thus the observed trend of leukemia and cancer risk among childhood survivors is clearly a life-long persistent phenomenon. Atomic bomb radiation certainly injured stem cells of each organ in 1945 and such injured stem cells continued to live, producing organ cells during a survivors' entire life. Some of such cells eventually transformed to cancer.[4]

Psychological effects of experiencing atomic bombs

The above mentioned bodily effects of the atomic bombs are widely known to survivors as the most important late effect of atomic bomb radiation. Therefore, the healthy survivors are long captured by a fear of suffering from leukemia or cancer. In 1995, psychological studies employing World Health Organization methodology clearly indicated such a long-persisting psychological instability, including depression and post-traumatic stress disorder (PTSD) among many survivors. Those who lost their relatives by the bombs and those who suffered from acute radiation sickness tended to have more pronounced psychological instability. Their health condition typically deteriorates around August every year. Radiation fear is a common clinical problem when physicians examine survivors' health condition once a year, according to Japanese Government policy.[5]

Second generation of survivors

Children of atomic bomb survivors have been intensively investigated to reveal any increase in the rate of malformation, leukemia, and cancer. So far such investigations have not obtained positive results.[6] However, many studies using animal experiments by irradiating the parent mouse and observing malformation and cancer in F1 (second generation) mouse have revealed positive results.[7] These findings induced a considerable anxiety among the second generation of survivors. A large-scale epidemiological study is currently being conducted. The second generation population, comprising approximately 200,000 people, are now passing into the cancer-prone age of fifty to sixty years old. If positive results of increased risk of leukemia and cancer will be obtained in future, it can be concluded that the atomic bomb is a human gene-targeted weapon that induces hereditary transmission of malignant diseases.

Socio-economic destruction of whole cities

The two cities were entirely devastated and flattened. More than 50% of citizens died in Hiroshima and more than 30% in Nagasaki. City infrastructure for human living was also completely destroyed, becoming a significant threat to survivors, especially those who suffered from radiation sickness and who lost their family members, houses, and treasure. The Japanese government and local governments could not provide any meaningful support until Japan became economically recovered around 1955.

Unrestricted perish of human lives

The magnitude of physical effects of an atomic bomb of Hiroshima or Nagasaki size well exceeded the force needed to destroy military facilities in the cities. Civilian areas, full of Japanese wooden houses; schools; many social facilities such as municipal halls; hospitals; gas stations; public communication sites such as newspaper, telephone, and radio broadcasting; transportation; and markets and stores to obtain food and daily living goods were all completely destroyed.

Human lives, irrespective of whether they were military personnel or civilians, were totally lost. In many families, all members were killed and often only children survived, becoming orphans. The latter caused a social problem in both cities during the regeneration period. Survivors faced this terrible situation and could not receive medical care and social aid. Many people lost the will to live for a long period, losing jobs and incomes.

Conclusion

People who died by the direct effects of the bomb were killed by three different forces in one moment. Survivors faced a terrible period of no medical care, no food, and no living goods. The will to live was lost by many. The long-term effects of radiation appeared as leukemia and cancer. Atomic bomb survivors continue to suffer fear of these diseases still 67 years after the bombings. The second generation people born to the Hiabakusha also have an anxiety of the hereditary effect of atomic bomb radiation. The disastrous humanitarian consequences and the horrendous nature of an atomic bomb is thus apparent.

Psychological studies employing World Health Organization methodology clearly indicated such a long-persisting psychological instability, including depression and post-traumatic stress disorder (PTSD) among many survivors.

Notes:

1 *The Medical effect of the Nagasaki Atomic Bombing*, Atomic Bomb Disease Institute; http://www-sdc.med.nagasaki-u.ac.jp/abomb/index_e.html

2 D.L. Preston, et al., *Cancer incidence in atomic bomb survivors. Part III. Leukemia, Lymphoma and Multiple Myeloma, 1950-1987* (1994), Radiation Research, vol. 137 (2 supplement) S68-97

3 M. Iwanaga, et al., *Risk of myelodysplastic syndromes in people exposed to ionizing radiation: a retrosepctive cohort study of Nagasaki atomic bomb survivors* (2011), Journal of Clinical Oncology, vol. 29, No.4, pp. 428-434

4 D.L. Preston, et al., *Studies of mortality of atomic bomb survivors. Report 13: solid cancer and noncancer disease mortality: 1950-1997* (2012), Radiation Research, vol. 178, No. 2, AV146-1472

5 S. Honda, et al., *Mental health conditions among atomic bomb survivors* (2002), Psychiatry and Clinical Neuroscience, vol. 56, No. 5, pp. 575-583

6 S. Izumi, et al., *Cancer incidence in children and young adults did not increase relative to parental exposure to atomic bombs* (2003), British Journal of Cancer, vol. 89, pp. 1709-1713

7 T. Nomura, *Role of radiation-induced mutations in multigeneration carcinogeneisis* (1989), IARC Scientific Publication, vol. 96, pp. 375-387

Nuclear weapons tests, fallout, and the devastating impact on Marshall Islands environment, health and human rights[1]

Dr. Barbara Rose Johnston

Following World War II, the Marshall Islands became part of the Trusteeship of the Pacific. In 1946, after the detonation of two atomic bombs in the Bikini lagoon, the United States was given the authority to administer the islands as a Strategic Trusteeship.[2] The terms of this agreement included the US obligation to "protect the inhabitants against the loss of their lands and resources" and "protect the health of the inhabitants of the Trust Territory".[3]

Between 1946 and 1958 the United States tested 67 nuclear weapons on or near Bikini and Enewetak atolls, atomizing entire islands and blanketing the entire Marshallese nation with measurable levels of radioactive fallout from 20 of these tests.[4]

The total explosive yield of nuclear militarism in the Marshall Islands was 93 times that of all US atmospheric tests in Nevada; the equivalent of more than 7,000 Hiroshima bombs. Iodine-131 comprised an estimated two percent of the resulting radioactive fallout.

US military testing in the Marshall Islands also involved an array of scientific tests: studies on ecological baseline; biological effects of radiation; the nature and behavior of radioactive fallout in the atmosphere, marine, and terrestrial environment; and the bioaccumulation of radioisotopes in the environment, food chain, and human body.[5] Hydrogen bomb tests, especially the March 1, 1954 Bravo Test, were immensely destructive.[6] Communities living immediately downwind suffered near fatal exposures and residents of Rongelap, Ailinginae, and Utrik Atolls were evacuated.[7] Residents of other islands and atolls in the northern chain also received dangerous levels of fallout, though these populations were not evacuated.[8] Bravo Test fallout also severely injured the 23 Japanese crew members of Daigo Fukuryu Maru, who were in Marshallese waters harvesting a school of tuna when fallout blanketed their vessel. One of the crew members, Kuboyama Aikichi, died a few weeks later.

Human radiation experimentation and adverse health effects

Once evacuated in 1954, the heavily exposed people of Rongelap were enrolled as human subjects in Project 4.1, a classified medical research programme documenting the effects of acute radiation exposures. In 1957, the people of Rongelap were returned to their homelands, moving into newly built homes on islands still dangerously contaminated from prior nuclear

Over the 12 years of bombing, some 8 billion curies of I-131 were released into the atmosphere above the Marshall Islands: 42 times greater than the 150 million curies released as a result of the testing in Nevada, 150 times greater than the 40 million curies released as a result of the Chernobyl nuclear disaster.

Credit: The Official CTBTO Photostream/ US Government

weapons tests and vulnerable to the fallout from the subsequent 33 nuclear bombs detonated in 1958.

First annually, and then biannually, the US medical teams visited by ship to examine, with x-ray, photos, blood, urine, and tissue samples, the relative health of the community. For more than four decades these studies continued with a total of 72 research excursions to the Marshall Islands involving citizens from Rongelap, Utrik, Likiep, Enewetak, and Majuro Atolls. Some 539 men, women, and children were subjected to studies documenting and monitoring the varied late effects of radiation, often with abusive procedures that took place without meaningful informed consent. Some Marshallese received radioisotope injections, underwent experimental surgery, and were subject to other procedures in experiments addressing scientific questions that, at times, had little or no relevance to medical needs and at times involved procedures that were detrimental to their health.[9]

lagoon sediments, coral reefs, and reef fish, with alarming levels in goat fish liver. This knowledge was not shared with the scientific world until 1972, nor shared with Marshallese until the declassification order supporting an Advisory Commission on Human Radiation investigation forced bilateral disclosure to the Marshall Islands government in the 1990s. The movement of cesium through the soils, and bioaccumulation in coconut crabs, trees, and fruit—a primary sources of food and liquid in the Marshallese diet—was also documented, with restrictions on the consumption of coconut crab periodically issued, without explanation.

These studies generated an array of findings including the recognition that acute exposures to radiation stimulate short-term effects and late effects can emerge many years following initial exposure. Other findings included recognition that radioiodine-131 adheres to and accumulates in the thyroid, stimulating the production of benign and cancerous nodules and interfering with the production of hormones, leaving pregnant

Human radiation experimentation records declassified in the 1990s demonstrate degenerative health outcomes from radiation exposure including: changes in red blood cell production and subsequent anemia; metabolic and related disorders; immune system vulnerabilities; muscoskeletal degeneration; cataracts; cancers and leukemia; miscarriages, congenital defects, and infertility.

The Rongelap study was structured in ways that required the involvement of children from other atolls to serve as control subjects. Age-matched subjects were selected by local authorities and their forced involvement occurred without informed consent. Being singled out resulted in social stigmatization (people were shunned because of the social perception that all people studied by the medical survey team were damaged by radiation). These children underwent the same examinations as the "exposed" subjects: photographs and x-rays; measurement of internal radiation with whole-body counters; the sampling of blood, bone marrow, skin, and other tissue; and, on a number of occasions, the injection of radioisotopes, vaccines, and other non-explained substances. The experience of serving as a research control was intrusive, painful, and potentially harmful to the health of the participant.

The classified scientific research programme also involved the long-term effort to document the presence and movement of radioisotopes in the environment and food chain. For example, radioiron (Fe-55) in fallout from the 1958 nuclear tests was documented in terrestrial and marine environments, including

women and children especially vulnerable. People who were not exposed to an acute level of ionizing radiation but were exposed to low-levels on a daily basis because they lived in an area contaminated by fallout also developed thyroid and other radiogenic problems.

The relationships between nuclear weapons testing, fallout, contamination of the environment, human subsistence in that environment, and degenerative health were not explained to the Marshallese until decades had passed. Human radiation experimentation records declassified in the 1990s demonstrate degenerative health outcomes from radiation exposure including: changes in red blood cell production and subsequent anemia; metabolic and related disorders; immune system vulnerabilities; muscoskeletal degeneration; cataracts; cancers and leukemia; miscarriages, congenital defects, and infertility. Declassified documents also demonstrate that US scientists fully expected adverse health effects to not only occur in the first generation of people exposed to fallout, but in the subsequent generations of people who live in a contaminated setting. Marshallese health records bear out these expectations.

Intergenerational ramifications of nuclear explosions

Today in the Marshall Islands the biodegenerative consequences of this abusive history alters and affects all aspects of life. In a nation that lacks a single oncologist or cancer treatment facility, the Marshallese experience extremely high rates of cancer; degenerative conditions associated with radiation exposure; miscarriage and infertility; and, the birth of congenitally deformed children. They endure the problems associated with raising physically disabled children, caring for increasingly feeble elderly, suffering from the fear and anxiety of additional exposures, and confronting the reality of intergenerational effects.

The majority of nuclear survivors from Bikini and Rongelap live in exile, largely on borrowed or rented Marshallese land on Kwajalein, Majuro, or Kili Atolls, in Hawaii, or in the continental US. Attempts to remediate radiation hotspots on areas of some islands and to rebuild homes on the island of Rongelap suggest that that someday soon, people may have the choice of returning home.[10] However, given the degree of contamination and remediation limitations, return to a traditional self-sufficient way of life in heavily contaminated atolls like Rongelap is impossible.

In 2002, research commissioned by the RMI Nuclear Claims Tribunal determined the presence of dangerous levels of radiation on six atolls in the southern part of the nation.[11] Given the bioaccumulative nature of the contamination caused by the nuclear testing, population-wide low-level exposure continues via the consumption of local shell and reef fish, fruits, vegetables, coconut crab, pigs, chickens, and other animals; inhalation of dust and cooking fire smoke; and drinking contaminated water.

Exposure to environmental hazards that humans cannot see, feel, or smell not only causes injury and degenerative change in biological systems, such conditions warp the very fabric of society, undermining individual, family, and societal health and the social and cultural systems that traditionally sustain that health. For Marshallese elders, radiation has attenuated their role in society, undermining the value of the traditional knowledge passed to them by previous generations. When communities cannot live on their home islands, knowledge and stewardship customs become increasingly irrelevant to daily life, and the respect accorded to elders, the keepers of such knowledge, diminishes. For Marshallese men, the traditional food provider for their families, self-worth is challenged when men lack opportunities to fish or gather food, and lack the skills and education to provide for their families in diaspora. Marshallese women have suffered and continue to suffer from the effects of radiation exposure in unique ways. Stillbirths, miscarriages, the inability to conceive, and gross deformities in offspring are rampant in the Marshall Islands, particularly in communities exposed to large doses of radiation. Marshallese women developed new words to describe their reproductive failures, words they did not need before the testing programme. Many Marshallese women face stigmas and fears about marriage or reproduction because of concern that the radiation will continue to compromise successive generations. For the youth, who are second, third, and now fourth generation nuclear survivors, the challenges are complex as the

traditional means to sustain life and livelihood erode, yet at the same time, the challenges of life in a radioactive nation drives innovative change.

For all generations, access to adequate healthcare remains a critical problem. While many Marshallese experienced fallout from one or more nuclear weapons tests, only those exposed to one detonation, the 1 March 1954 Bravo test, are eligible for US-funded medical treatment when radiogenic disease occurs. Chronic exposure generates cumulative and synergistic effects, especially cancer. With independence in 1986 the Marshall Islands government inherited a grossly inadequate health care system, one that historically relied upon US funding and infrastructure to transport and treat. Lacking internal technical capacity, medical infrastructure, and the economic means to address healthcare needs at home, for the Marshallese, medical migration became a societal norm.

In a nation that lacks a single oncologist or cancer treatment facility, the Marshallese experience extremely high rates of cancer; degenerative conditions associated with radiation exposure; miscarriage and infertility; and, the birth of congenitally deformed children.

Current conditions

The RMI Islands Nuclear Claims Tribunal recognizes some 36 forms of radiogenic cancers and disease as resulting from nuclear weapons test exposures. A review of Tribunal awards in 2007 found that most awards were for thyroid cancers and disease, pulmonary and lung cancer, cancers of the blood, bone marrow, and lymph nodes, breast cancer, and cancers of the ovary.[12]

Chronic and acute radiogenic exposure also impacts immune system response, creating a population-wide vulnerability to infectious and non-communicable diseases.[13] For example, worldwide some one-third of the human population carries the bacterium for tuberculosis; but most people do not become sick as their immune systems fight off infection.[14] In 2005, the Marshall Islands the tuberculosis rate was some 23 times the rate of the United States.[15] In 2011, Marshallese mortality rates for tuberculosis were the highest rate in the Pacific and fourth highest in the world.[16] Other infectious diseases run rampant.[17] Non-communicable diseases and degenerative health conditions, especially conditions associated with radiation-exposure and life in a heavily contaminated environment, are crippling an already over-taxed health infrastructure.

Comparing the relative health of US residents with the Marshallese is insightful. In the US, the diabetes prevalence rate is 9.35 percent. In the Marshall Islands the rate is 27.06, the third highest rate in the world, and diabetes is the number one cause of death.[18] Infant mortality in the United States is about 6 deaths per thousand; in the Marshall Islands the 2012 rate is about 23 per thousand, a rate comparable to Kazakhstan, another nation victim to nuclear testing.[19] On average, Americans live to 77.5 years old; in the Marshall Islands longevity is 62 years.[20]

Reparation and the right to remedy

Given the many constraints and impossibilities in this heavily polluted context—atomized islands, high-level nuclear waste dumps, chronic and acute health effects to individuals in the past, present, and in the generations to come—meaningful remedy requires restoration of a healthy and sustainable way of life with respect for the full array of needs, rights, and dignity of this indigenous nation.[21]

In his 2012 mission report on the Marshall Islands and the United States, Mr. Calin Georgescu, the United Nations Special Rapporteur on the implications for human rights of the environmentally sound management and disposal of hazardous substances and waste, observes that the human rights consequences of nuclear contamination involve, at the most fundamental levels, the loss of a healthy environment that sustains a viable, culturally-distinct, Pacific island way of life.[22] Reparation should restore a culturally-vibrant, healthy, sustainable way of life for the Marshallese people.

What does this requires in concrete terms?

(1) Full disclosure, cooperation, and assistance from the United States in addressing the environmental contamination and human health ramifications of past and current military use of the Marshall Islands, including records associated with biological, chemical, nuclear, and other weapons testing; full access to data associated with environmental surveys; and, full access to the medical records and related records of scientific research involving Marshallese subjects and their biological samples, including genetic samples.

(2) Actions of acknowledgement, apology, and amends to the Marshallese people for the many damages resulting from UN Strategic Trust designation and the United States military activities, harmful exposures, and related human subject experimentation in the Marshall Islands, including full funding by the United States of the Marshall Islands Nuclear Claims Tribunal awards to addressing past and future claims; expansion of nuclear health treatment and compensation programs to include the injuries of remediation workers; and the personal health impacts that extend across the nation and the generations.

(3) Mutual engagement in building, staffing, and sustaining a comprehensive health treatment system in the Marshall Islands that attends to the acute, chronic, and inter-generational effects of exposure to radiogenic and other toxic contaminants resulting from the military use of this nation.

(4) Environmental health monitoring and remediation systems to respond to new hazards resulting from downwind/downstream exposure to nuclear disasters in the region.

(5) Bilateral and international partnerships that develop the educational capacity, technical expertise, and related infrastructure to attend to the health, environment, and sustainable development needs of the Marshall Islands, with standards in remediation based on precautionary principles and a restoration praxis which emphasizes innovation in science and technology.

(6) Actions that demonstrate a guarantee of non-repetition in the violations of bioethical norms and humanitarian law suggested by human subject experimentation and in the violations of humanitarian law resulting from the development, testing, and use of weapons of mass destruction.

Conclusion

The Marshall Islands experience with life and death in the US's nuclear "Pacific Proving Grounds" offers many lessons relevant to the larger world. The humanitarian consequences of nuclear devastation are not limited in time and space. Rather, health consequences and related societal burdens expand over time. Political efforts to attend to the human and environmental disaster resulting from nuclear fallout have historically served to limit economic liability by ignoring or denying the humanitarian reality of ulcerating conditions. What is now apparent in this seventh decade of life in, what in essence is, a nuclear war zone is that no single nation can attend to the complex environmental, human health, and societal needs in singular fashion. Understanding and attending to the full array of issues resulting from the use of nuclear weapons requires national, bilateral, regional, and global commitment and action.

Notes:

1 Unless otherwise noted, details are from Johnston and Barker, *Consequential Damages of Nuclear War: The Rongelap Report* (2008), Left Coast Press, Walnut Creek, CA.

2 An isolated array of tiny atolls and islands east of Micronesia, this nation was selected by the United States to serve as the atomic proving grounds for the 1946 Operation Crossroads, an atomic war games exercise involving some 42,000 service men and scientific personnel, global press, and international observers (UN delegates from Australia, Brazil, Canada, China, Egypt, France, Great Britain, Mexico, the Netherlands, Poland, and the Soviet Union). Able exploded in the atmosphere above Bikini lagoon; the second bomb, Baker, detonated in the lagoon itself, sending 2 million tons of radioactive water skyward. Both were 23-kiloton plutonium devices; about the same size as the bomb dropped over Nagasaki on August 9, 1945. See: Shurcliff, *Bombs at Bikini: The Official Report of Operation Crossroads* (1947), Prepared under the Direction of the Commander of Joint Task Force One, Wm. H. Wise & Co., Inc., New York.

3 Strategic Trust Territory Agreement between the United States and the United Nations, April 2, 1947 entered into force July 18, 1947, 61 Stat. 3301, T.I.A.S. #1665.

4 The human cost of this strategic trusteeship has been assessed many times over the years. See: Special Joint Committee Concerning Rongelap and Utirik Atolls, *A Report on Rongelap and Utrik to the Congress of Micronesia Relative to Medical Aspects of the Incident of March 1, 1954 - Injury, Examination and Treatment* (1973), Fifth Congress of Micronesia; G. Johnson, Micronesia: America's *'Strategic' Trust*, (1979), Bulletin of the Atomic Scientists Vol 35. No 2p.10-15; M. Gardner (Ed), Keeping the promise (2006), Harvard Law School; and Johnston and Barker (2008), op cit 1.

5 See: Dunning, *Radioactive Contamination of Certain Areas in the Pacific Ocean from Nuclear Tests: A Summary of the Data from the Radiological Surveys and Medical Examinations* (1957) US Atomic Energy Commission; Conard, *A Twenty-year review of medical findings in a Marshallese population accidentally exposed to radioactive fallout* (1975), BNL Technical Report 50424, Brookhaven National Lab, Upton, NY; Conard, *Fallout: The experiences of a medical team in the care of a Marshallese population accidentally exposed to fallout radiation* (1991), BNL Technical Report 4644, Brookhaven National Lab, Upton, NY. Independent reviews of the environmental and human effects research record occurred following declassification in 1995, see Johnston and Barker (2008), op cit 1; and Rudrud, et al., *The Sea Turtle Wars: Culture, War, and Sea Turtles in the Marshall Islands* (2007), SPC Traditional Marine Resource Management and Knowledge Information Bulletin #21, pp.3-29

6 A. Breslin and M.E. Cassidy, *Radioactive Debris from Operation Castle, Islands of the Mid-Pacific* (1955), United States Atomic Energy Commission, New York: New York Operations Office. Declassified by the U.S. in 1994 and delivered to the Republic of the Marshall Islands (RMI) in 1995, this document reports significant levels of radiation from fallout measured in 1954 at sites on twenty-eight atolls, of which twenty-two were populated during Operation Castle (March 1 through May 14, 1954). Thus, regardless of location in the Marshall Islands during Bravo Test, all residents were exposed to radioactive fallout as result of the atmospheric weapons tests, a finding reconfirmed by H. Behling, J. Mauro, and K. Behling, *Final Report: Radiation Exposures Associated with the U.S. Nuclear Testing Program for Twenty-one Atolls/Islands in the Republic of the Marshall Islands* (2002), S. Cohen and Associates, McLean, VA.

7 Evacuation occurred a full day after military personnel was evacuated from nearby Rongerik. See: Ann C. Deines, D. I. Goldman, et al., *Marshall Islands Chronology:1944-1990* (1991), History Assoc. Inc., US Dept of Energy. *Estimation of the Baseline Number of Cancers Among Marshallese and the Number of Cancers Attributable to Exposure to Fallout from Nuclear Weapons Testing Conducted in the Marshall Islands* (2004), National Cancer Institute; http://dceg.cancer.gov/RMIdocs/9-28Response_appendix.pdf

8 The USS Renshaw visited Likiep on March 6, 1954 documenting high levels of radioactivity. Citing the logistical problems of moving a large population, the U.S. opted to leave residents in situ with no medical aide or assistance. Fish samples were collected in a second visit later that year, and in 1955, a medical survey of the population was conducted (taking blood and urine samples).

9 Seventy-nine Marshallese subjects received Cr-51 and/or tritium as part of non-treatment-related research (1961, 1966), and between five and twenty-five subjects received Cr-51 during the 1959 medical survey. Several of these experiments also involved Caucasian Americans living in the Marshall Islands. In at least three instances, Cr-51 was injected in young women of child-bearing age. This human radiation experimentation was recognized as an abusive violation of fundamental rights.
See: Johnston and Barker (2008), op cit 1; Advisory Committee on Human Radiation Experimentation, The Human Radiation Experiments: Final Report of the President's Advisory Committee, (1995), Washington, DC: U.S. Government Printing Office; Marshall Islands Nuclear Claims Tribunal April 17, 2007 judgment in the Rongelap claim, http://www.nuclearclaimstribunal.com/rongelapfin.htm#_ftn76.

10 *Marshall Islands Dose Assessment & Radioecology Program*, US Department of Energy: https://marshallislands.llnl.gov/documents.php

11 Beheling, Mauro and Behling (2002), op cit 6

12 Due to failure of the United States to fully fund the Tribunal, no personal injury claim has been paid in full. (Johnston and Barker(2008),op cit 1,), p. 242

13 Brookhaven Lab medical surveys document changes in red blood cell production, bone marrow function, and chronic disease in radiation-exposed populations (Conard et al., op cit 5). Research conducted by the Atomic Bomb Casualty Commission (and, later, the Radiation Effects Research Foundation) demonstrated immune cell response to radiation and the finding that "persons with higher radiation exposures have lower numbers of CD4 T cells and elevated levels of various inflammatory proteins in their blood" and "a slight dose-related decrease in immunity has been observed against certain viral infections. http://www.rerf.jp/radefx/late_e/immunity.html

14 *World Health Organization, Fact Sheet No. 104*, (Revised March 2006), The Global Fund, World TB Day 2005 and *WHO TB Fact Sheet* (2007), World TB Day 2007

15 *Trends in Tuberculosis - United States, 2005* (2006), Center for Disease Control; *Tuberculosis in the US-affiliated Pacific Island Jurisdictions*, USAPI 2005; G. Johnson, *Marshalls Top Northern Pacific in Tuberculosis* (2006), Pacific Islands Report, May 15, 2006

16 Tuberculosis death rates per 100,000 in 2011: Global rate of 14; Marshall Islands rate of 74; US rate of 0. Source: *Global Tuberculosis Report 2012*, World Health Organization

17 Beatty, et al., *An Outbreak of Vibrio cholera 01 Infections on Ebeye Island*, (2004), Clinical Infectious Diseases 38: pp.1-9; Hyde et al., *Measles Outbreak in the Republic of the Marshall Islands* (2003), International Journal of Epidemiology, 35(2): p.299

18 Comparative prevalence rate (% of the World Health Organization standard). See: *IDF Diabetes Atlas 5th Edition*,(2012), International Diabetes Federation-Total Prevalence of Diabetes & Pre-diabetes, (2007), American Diabetes Association; Williams: A. Hampton, *Barriers to Health Services Perceived by Marshallese Immigrants*, (2005) Journal of Immigrant Health, 7(4) October; Yamada,et al., Diabetes mellitus *prevalence in outpatient Marshallese adults on Ebeye Island, Republic of the Marshall Islands* (2004), Hawaii Medical Journal, 63(2): pp.45-51; *Diabetes Wellness Center Opens in Marshall Islands' Capital* (2007), US Embassy, Majuro, Marshall Islands, Press release, Jan 19, 2007 www.yokwe.net/index.php?name=News&file=article&sid=1367

19 CIA, The World Factbook, https://www.cia.gov/library/publications/the-world-factbook/

20 *Human Development Report 2006*, United National Development Program and *The World Health Report 2006*, World Health Organization

21 United Nations Declaration on the Rights of Indigenous Peoples (A/RES/61/295)

22 Report of the Special Rapporteur on the implications for human rights of the environmentally sound management and disposal of hazardous substances and wastes, Calin Georgescu - Addendum - Mission to the Marshall Islands (27-30 March 2012) and the United States of America (24-27 April 2012); http://www.ohchr.org/Documents/HRBodies/HRCouncil/RegularSession/Session21/A-HRC-21-48-Add1_en.pdf

Effects of a nuclear blast over Bombay

Dr. M.V. Ramana

Credit: Pond5/ HD_SFX

Introduction

The explosion of a Hiroshima-sized (15 kt) nuclear weapon over Bombay would result in 150,000 to 800,000 deaths within a few weeks from the combined effects of blast, burn, and radiation. A weapon with a yield of 150 kilotons could cause between 2,000,000 and 6,000,000 deaths. The use of nuclear weapons over any densely populated city in South Asia would result in similar casualty figures. Fallout- related cancers and other illnesses would increase the casualty totals over time. Treatment of blast, burn, and radiation injuries in a region with relatively few physicians and hospital facilities would be compromised further by the devastation of medical and transportation infrastructures. The only way to make certain that a tragedy of such proportions never happens is the complete, global abolition of nuclear weapons.

The recent series of nuclear tests conducted by India and Pakistan give particular relevance to an examination of what nuclear weapons and the possibility of a nuclear war would mean in a South Asian context. The effects of a nuclear weapon explosion are so immense and so different from those of conventional weapons[12] that it is useful to present, as a case study, a familiar hypothetical "target".

Therefore the effects of a single explosion of a Hiroshima-sized nuclear bomb (i.e., approximately 15 kilotons) at an elevation of 600 meters over Bombay (Mumbai), India, shall be described. The consequences of such an explosion for any other large, densely populated, South Asian city, such as Lahore or Dhaka would be similar.

The short-term effects of a nuclear explosion—those that occur within the first few weeks—can be classified as either prompt or delayed effects. In addition there are long term effects, primarily related to radiation from fallout that can develop over years.

Prompt effects

Initial Flash

Any person or object exposed to the explosion would first experience an extremely intense flash of heat and light, brighter than a thousand suns. Even looking at the flash could cause blindness. For 1.6-3.2 km around the point of explosion (the epicenter, or ground zero), everything that could burn—wood, paper, clothes, vegetation, and all other combustible materials—would catch fire.

Radiation

Exposure to neutron and gamma radiation, resulting from the nuclear reactions responsible for the explosion, would occur almost simultaneously. Radiation exposure could lead to a variety of symptoms such as nausea, bloody diarrhea, and hemorrhages within a few days (other consequences of radiation could appear years later)[3]. These health effects are often fatal and include leukemia, thyroid cancer, breast cancer, and lung cancer, as well as non-fatal diseases such as birth defects, cataracts, mental retardation in young children, keloids, and others.

Blast

The third effect is the shock or blast wave, which would result in a forceful blow to any person or object in its path. The winds accompanying the shock wave would reach velocities of more than 110 km/h to a distance of 3 km or more. The shock wave would destroy everything within a circle with a radius of 1.1 km. Up to 1.7 km from the point of explosion, all houses not built with concrete would be destroyed. Many of the buildings in Bombay, especially older ones, are either badly designed or constructed with raw materials that are of poor quality (such as adulterated cement or improperly baked bricks). Every year several hundred buildings collapse by themselves, especially during the rainy season. Faced with the shock wave and these hurricane-force winds, buildings may collapse at significantly greater distances than those estimated here.

Delayed effects

Firestorm

A few minutes after the explosion, the delayed effects would begin. The first of these is the firestorm that would result from the coalescing of individual fires started by the initial flash of light and heat[4]. In the case of a Hiroshima-sized explosion over a city like Bombay, the radius of the region under flames would be 1.7 to 2 kilometers. Due to the large area of the fire, the fire zone would act as a huge pump, sucking in air from the surrounding areas and driving heated air upwards. This pumping action would create winds with velocities as high as 50-80 kilometers/ hour. The temperature in the fire zone would reach several hundred degrees, making it almost certain that there would be no survivors. Furthermore, firefighting would be almost impossible due to the combination of hurricane-force winds, thick smoke, the destruction of water mains and tanks by the shock wave, and the presence of debris from the blast blocking roads and access routes.

Other factors would lead to a probability of small explosions in the fire region and, therefore, to a greater chance that people would be injured as well as burned. In Bombay, for example many houses contain gas cylinders (containing liquid petroleum gas) that are used for cooking. These are known to explode when exposed to fires. In addition, compared to cities in Japan and Germany during World War II, Bombay and other modern cities have much greater concentrations of motorized vehicles such as cars, scooters, and buses that use petroleum-based fuels. The corresponding storage and dispensing facilities for such highly inflammable and explosive fuels would only increase the numbers of causalities.

Fallout

The second delayed effect is radioactive fallout. One of the more graphic images from Hiroshima and Nagasaki was the black rain carrying radioactive fallout that descended after the explosion. As in those two cities, radioactive fallout would affect Bombay, but the quantities would be difficult to predict.

When a nuclear bomb explodes at low altitudes, a large amount of material is vaporized and carried aloft into the mushroom cloud. This material then mixes with the fireball's radioactive materials, which results in a cloud of highly radioactive dust. This radioactive fallout can travel large distances on the winds created by the explosion, as well as in the atmosphere, before ultimately falling back to earth. The effects of exposure to fallout are similar to those of exposure to nuclear radiation.

Bombay, being close to the sea, has high levels of water vapour in the atmosphere. Water droplets would likely condense around radioactive particles and descend as rain, as was the case in Hiroshima and Nagasaki. If, instead of assuming that the weapon is detonated at a height of 600 meters, we assume that the explosion hap- pens at the surface with a wind velocity of 25 km/h, the area subject to levels of fallout that have a high likelihood of being fatal would be about 25-100 square kilometres. The wind direction during the period that the

fallout is aloft (which could be fluctuating) would determine which areas would be subject to these levels of radioactivity. The regions subject to high levels of fallout would have high levels of casualties and radiation sickness.

Even people who live in areas subject to lower levels of radiation, unless they are immediately evacuated, would be susceptible to radiation sickness. Given the large population of Bombay and the likely damage to all forms of transportation infrastructure (train stations and tracks, roads, dockyards, airports, etc.) evacuation of survivors would be nearly impossible.

Population figures and casualty estimates

According to the 1991 census, the population of Greater Bombay is 9,910,000; if the neighbouring town of Thane is also included, the population is 12,572,000[5]. Since the decadal growth rate for Bombay during the decade preceding this census was 20.21%, these numbers may understate the current population significantly. Furthermore, there is also some evidence of undercounting in the 1991 census[6]. The average population density of Bombay is about 23,000 people per square kilometre. There are regions, however, where the population density exceeds 100,000 people per square kilometre.

Prompt causalities

Since a nuclear explosion and its effects are complicated physical phenomena, with different types of effects occurring around the same time, it is impossible to predict numbers of casualties or injuries with any reasonable accuracy. Assuming the above population densities, however, one would expect somewhere between 150,000 and 800,000 deaths within a few weeks of the explosion, resulting from just the blast and fire effects of one small (i.e., Hiroshima-sized) nuclear weapon, further assuming that the weapon is exploded in the atmosphere and that fallout effects are negligible (assumptions that lead to a very conservative casualty estimate). If the weapon used were to have a yield of 150 kilotons (i.e. ten times as large as the Hiroshima bomb), then the number of deaths would be about 2,000,000 to 6,000,000.

In the case of a weapon exploding at ground level, the areas damaged by fire and blast are somewhat less. But fallout would be a significant cause of deaths and sickness. Assuming that all the fallout is deposited in inhabited areas (with a population density of 23,000) the number of people dying of all causes could be as high as 350,000 to 400,000 for a 15-kiloton weapon. Many more people would be subject to lower doses of radiation, which in the case of already sick people, the old and the young, could well be lethal in the absence of medical care.

Long-term causalities

The above numbers include only the "prompt" casualties (i.e. those who are injured or die right away or within a few weeks of the explosion). Many more people will certainly die from long term effects, especially effects with radiation-related causes. Several hundred Hiroshima survivors have died from leukemia, thyroid cancer, breast cancer, and lung cancer[7]. Studies involving survivors at Hiroshima and Nagasaki reveal that the mortality rates for all diseases, for leukemia, and for malignancies other than leukemia, among people exposed to more than 200 rads, were 1.16, 17.6, and 1.42 times higher respectively, when compared to a control group that had not been exposed to radiation[8]. Leukemia accounts for 3% of all cancers for males and 3.5% of all cancers for females in Bombay[9]. Increases in the cancer rates of survivors of an atomic bombing of Bombay should be comparable to those among Hiroshima survivors.

There are a number of other reasons to believe that the casualty numbers cited above would be an underestimate in a city like Bombay. First, the assumed population densities are lower than the actual densities. Apart from undercounting and variations among regions, a substantial number of people come in every day from places as far away as Pune (four hours by train) to work in Bombay. The census does not take such commuters into account. Since an attack from the air is quite likely to take place during the day in order to maximize visibility, many commuters will also be killed or injured.

Second, casualties from fallout have not been included in the estimates. Since fallout, even if present only in small quantities, can spread out to large regions and cause local hot spots, this is an important omission.

Third, there are large numbers of industries in Bombay and its vicinity. India's highest concentration of chemical industries is in the Trans-Thane creek area, which has more than 2,000 factories. Central Bombay is home to several mills, which could cause additional fires and explosions, and which could spread toxic substances. The Union Carbide accident in Bhopal is an example of the kinds of effects that are possible due to escape of toxic chemicals. In addition to chemical industries, the largest nuclear laboratory in India — the Bhabha Atomic Research Centre — is in Trombay, just outside Bombay. A nuclear explosion in the vicinity of either reactor at the Centre (CIRUS and Dhruva) or near the reprocessing plant or the facilities storing radioactive waste and/or spent fuel could lead to the release of large amounts of radioactivity in addition to the quantities resulting from the explosion itself. This would increase the amounts of fallout significantly.

Fourth, conservative figures for blast damage and fire regions have been deliberately chosen. The actual areas are likely to be higher, implying a greater number of casualties. Hospitals and medical care in an overcrowded city such as Bombay are limited to begin with, and facilities within the affected area would be destroyed or damaged during the attack. The injured would be unlikely to find medical treatment to help them survive.

Conclusion

The immense scale of effects resulting from a single fission weapon with a low yield should make it clear that the use of nuclear weapons in South Asia would lead to a major catastrophe. The only guarantee that such a tragedy will never occur is the global elimination of nuclear weapons and of the means to manufacture them.

Credit: Pond5/ Imagex

Notes:

1 I.S. Glasstone IS and P.J Dolan, *The Effects of Nuclear Weapons* (1977), Department of Defense/Energy Research and Development Administration, Washington, DC.

2 Office of Technology Assessment. *The Effects of Nuclear War (1979),* US Congress, Washington, DC

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7 Committee for the compilation of materials on damage caused by the atomic bombs in Hiroshima and Nagasaki, *Hiroshima and Nagasaki—The Physical, Medical and Societal Effects of the Atomic Bombings* (1981), Basic Books, New York

8 Ibid

9 R.G. Sharma, M.S. Maheshwari, S.C. Lodha, *Cancer profiles in western Rajasthan* (1992),Indian Journal of Cancer, issue29,pp 126-132

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Preventing the unacceptable

Beatrice Fihn

In this publication, health professionals, researchers, academics, and experts have observed and examined the consequences of any use of nuclear weapons. Approaching the topic from different perspectives, each chapter contributes to painting a clear picture of the devastation and suffering that would result from the use of nuclear weapons, and highlight our inability to control and limit the effects of these weapons both in time and space.

As explained in the chapters of this publication, a nuclear weapons detonation causes an initial blast, heat wave, fires, radiation, radioactive fallout, and electromagnetic pulse. During the initial blast the pressure wave causes direct injuries, structural collapse and transforms objects and people into missiles hurtling through the air and into one another. The temperature of a nuclear fireball is in the range of 1 million to 100 million degrees Celsius. This results in both direct (flash) burns of any exposed living thing and flame burns from fires that ignite over a wide area. The ignition of numerous fires would consume all flammable materials and available oxygen, and the number of direct deaths caused by these fires would be 3–4 times that caused by the blast itself. Anyone who instinctively glances at the fireball would risk flash blindness and retinal burns. In addition, the initial pulse of neutrons and gamma rays emitted from a nuclear explosion would irradiate all living things directly exposed.

Though not as dramatic or obvious as the blast, fire, and radiation effects, an electromagnetic pulse would wreak havoc on electronic equipment. Electricity cables, telephone lines, railways, and antennae would be effected and impact computers, electronic equipment and circuitry essential for telecommunications, computer systems, transport networks, and water and electricity supplies. Commerce and trade could come to a standstill without functional electronic systems. The electromagnetic pulse would cause additional victims by preventing modern health care equipment from functioning correctly. Relief efforts would also be hampered by disruptions in radio and telephone communications, essential for emergency response efforts.

In addition to the immediate and the long term human suffering caused by exposure to radiation, a nuclear explosion would also cause an environmental catastrophe, as the local surroundings would be severely impacted by both radiation (fallout) and non-radiation (fire, blast, shock). Animals would suffer from similar fates as humans, such as burns, radiation sickness, and cancers. There would also be a genetic impact on plants and animals that could be compounded as radioactive residue makes its way along the food chain. A scenario with a limited exchange of nuclear weapons, such as a regional nuclear war, would cause significant climate disruption worldwide and lead to a serious decline in agricultural production, potentially resulting in catastrophic food shortages on a global scale and massive starvation for the world's already vulnerable populations.

As shown in the section on economy and development, the impact of a nuclear weapon detonation would not be limited to direct effects on human beings and the environment. Any use of nuclear weapons would also negatively effect the global economic system, development goals, and migration.

For example, an explosion of one single nuclear weapon or more anywhere in the world would impose economic costs well beyond those of a major natural disaster. In major urban areas, the costs of the immediate destruction and longer-term economic disruption could easily run into tens of billions—and possibly as high as hundreds of billions—of US dollars. In addition, the economic impact of a nuclear explosion is also likely to have large economic consequences at great distances from the initial blast radius.

The use of nuclear weapons would affect not just the global economy, but also related issues such as development, poverty, and hunger. Interruptions to the supply of food and petroleum within the country where the nuclear explosion has occurred; disruptions to the global supply of goods and its impact on the local economy, the business sector, and the stock market; damage to infrastructure, lives, and livelihoods; and resulting forced or voluntary migration—all have direct impacts on the levels of poverty and development in the affected country.

A nuclear explosion would take place in a context that is already challenging for developing countries and would undermine the achievement of the Millennium Development Goals (MDGs). And while the immediate impact of a nuclear weapon explosion will not discriminate between rich and poor, long-term consequences will disproportionally affect the most vulnerable communities around the world.

When looking at the catastrophic humanitarian harm that nuclear weapons would cause, it becomes evident that no response capacity would be enough to provide relief or help to victims. Members of emergency services, other disaster responders, health care professionals, and the many people who may be called to assist in responses to humanitarian emergencies would face unique dangers and difficulties following any nuclear explosion. Widespread and persistent radioactivity would severely complicate and hamper access and relief efforts. In the words of Dumas and Coupland (2007), almost seventy years after the atomic bombings of Hiroshima and Nagasaki, "no government, international organization, non-governmental organization or collaborative body has either realistic plans or the capacity to mount an effective international assistance response in the event of a nuclear detonation."[1]

The research that has been presented in this publication highlights the growing need for the international community to declare both the use and the possession of nuclear weapons as unacceptable, as there is no legitimate situation in which the impact of the use of a nuclear weapon can be justified.

Since 2010, many governments and international organizations have contributed to an increased focus on the humanitarian impact of nuclear weapons. This represents a clear break away from the traditional state-centric perspective, which mainly has discussed and considered these weapons purely in terms of geopolitics, strategic balance and deterrence. By shifting the focus away from the theoretical abstractions of classic deterrence theory and towards the actual impact and consequence of the use of these weapons, their very legitimacy is being seriously challenged.

A significant starting point in the shift in the discourse was a speech in April 2010 by the then-President of the International Committee of the Red Cross (ICRC), Jakob Kellenberger, in which he highlighted the unacceptable humanitarian impact of nuclear weapons and noted that the ICRC would be unable to respond to any use of nuclear weapons.

The statement was followed up by a reference in the outcome document of the 2010 nuclear Non-Proliferation Treaty (NPT) Review Conference, adopted by consensus by all 189 states parties:

> *The Conference expresses its deep concern at the continued risk for humanity represented by the possibility that these weapons could be used and the catastrophic humanitarian consequences that would result from the use of nuclear weapons.*[2]

In November 2011, the Council of Delegates of the Red Cross and Red Crescent movement adopted a resolution that emphasized the "incalculable human suffering that can be expected to result from any use of nuclear weapons, the lack of any adequate humanitarian response capacity and the absolute imperative to prevent such use", and further called on all states to conclude negotiations of a treaty to prohibit the use of and eliminate nuclear weapons.

The NPT Preparatory Committee in 2012 and the First Committee of the General Assembly in 2012 saw an increasingly larger number of states reference the catastrophic humanitarian consequences of the use of nuclear weapons and called for intensified efforts to outlaw them.

This movement indicates that more and more actors consider it crucial to improve our understanding of the concrete consequences of the use of these weapons. The humanitarian approach also makes both civilized states and concerned citizens fundamentally question the continued maintenance and modernization of enormous stockpiles of nuclear weapons,

Few people deny that using nuclear weapons would have a catastrophic impact on populations and the environment, and even the nuclear-armed states seem to agree that the world would be better off without them. It is not possible to protect populations from a nuclear attack; the only way is to prevent such an attack from ever taking place.

Preventing the use of nuclear weapons is not a new idea. Most nuclear non-proliferation initiatives are aimed at preventing the spread of nuclear weapons—and especially preventing them from falling into the "wrong hands". Of course, as UN Secretary-General Ban Ki-moon recently noted, "There are no right hands for the wrong weapons."[3] While the NPT has served the community well as a non-proliferation tool, it has failed to achieve any real disarmament, despite the obligation of States Parties to do so. The possessors of nuclear weapons often portray non-proliferation and arms control measures as the only way to prevent nuclear weapons from ever being used. For example, ratifying the Comprehensive nuclear Test-Ban Treaty (CTBT) and negotiating a Fissile Material Cut-off Treaty (FMCT) is repeatedly called "the next logical step" towards disarmament. However, neither of these treaties are capable of reducing the current risk of the use of nuclear weapons, they are only measures intended to prevent further proliferation.

There are some international initiatives focused on reducing the risk of the use of nuclear materials, as well as for developing nuclear weapons, such as the ongoing process around nuclear security, initiated by US President Obama in 2010, and the Global Initiative to Combat Nuclear Terrorism. However, just as with the CTBT and the FMCT, these measures do not reduce the current capabilities of the nuclear possessing states and do not address the threat of existing arsenals.

Aside from non-proliferation initiatives, some bilateral and unilateral efforts to reduce stockpiles have been taken. The New Strategic Arms Reduction Treaty (START), for example, negotiated by the United States and Russia lowered the number of deployed strategic nuclear warheads for each country to 1,550 (although only one warhead is counted per bomber, irrespective of how many bombs it actually carries). In addition, the United Kingdom announced it will reduce its overall nuclear weapon stockpile to "no more than 180" by the mid 2020s.

While reductions are positive steps, the nuclear weapon possessors still maintain these weapons as potential tools of war and continue to invest billions of dollars in modernization programmes. In addition, these reductions have been carried out without reducing any state's capacity to launch an attack at any target, thereby maintaining the ability to unleash a humanitarian catastrophe that would impact the entire world, especially its most vulnerable communities.

If one agrees that the humanitarian impact of a nuclear weapons explosion would indeed be unacceptable, it is obvious that any solution that does not address existing stockpiles or reduce the nuclear capability of possessors can never be adequate. Therefore, the elimination of all nuclear weapons is the only credible way to protect humankind against the scenarios that this publication describes.

Elimination of nuclear weapons has been on the to-do list for the international community for 67 years.[4] And in 1970, the five nuclear weapon states agreed to negotiate, in good faith, nuclear disarmament. Yet, no multilateral disarmament of nuclear arsenals has ever taken place. Nuclear weapons have somehow been portrayed as an almost magical thing, something that is beyond our understanding—and ultimately beyond our control.

By focusing on the humanitarian impact and the consequences of any use of nuclear weapons, it becomes clear that these weapons are not connotations of power or mythical weapons of stability. Nuclear weapons are quite simply inhumane, unacceptable, and appalling weapons of terror, and just like chemical and biological weapons, no state should be proud to possess them or aspire to acquire them. Maintaining nuclear weapons is not a symbol of power or strength, but instead a constant reminder of the immense suffering that they have caused and continuously threaten to cause again.

The effects of nuclear weapons reach beyond borders, beyond the traditional notions of the nation-state, to impact our environment, economy, food production and commerce; to undermine development goals and to catastrophically harm people the world over. It is therefore the responsibility of all countries, in particular those without nuclear weapons, to show stronger leadership in outlawing and eliminating these weapons.

Notes:

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4 The first resolution ever adopted by the United Nations in 1946 called for the elimination of nuclear weapons.

Reaching Critical Will

Reaching Critical Will and Women's International League for Peace and Freedom is a partner organization of the International Campaign to Abolish Nuclear Weapons (ICAN).

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