The Medical and Ecological Effects of Nuclear War

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Though the task of describing the horrible medical and ecological effects of a nuclear war is disagreeable, it is also essential. Only when the leaders of the Warsaw Pact and NATO nations are made more afraid of such a war than they are of each other, will significant nuclear weapon reductions be achieved. Historical analogies to the bombs dropped on Hiroshima and Nagasaki are not very useful. Today's weapons are vastly more numerous, powerful and sophisticated. The author paints a vivid picture of the immediate effects of a one megaton explosion detonated two miles above a city — a third of the population dead, another third seriously injured, many to die because of a total lack of medical assistance. But this is only the beginning. Longer term effects of a nuclear detonation — contaminated food and water, devastating epidemics, local radioactive fallout, and the disappearance of the instruments of social order — would make survivors desperate, even envious of those less "fortunate". Finally, the author speculates as to the long term effects of nuclear radiation, including cancers that would plague persons exposed, possible genetic damage to their offspring and the biological consequences of a long-contaminated environment. He concludes that a nuclear war would create a different world, one in which the war's causes would have become simply irrelevant.

Bien que cela soit désagréable, il est essentiel de décrire les effets médicaux et écologiques horribles d'un conflit nucléaire. Des réductions sensibles des stocks d'armes nucléaires ne seront possibles que lorsque les leaders des nations membres du Pacte de Varsovie et de l'OTAN apprendront à craindre l'éventualité d'un tel conflit plus qu'ils ne se craignent les uns les autres. Les rappels historiques aux bombes larguées sur Hiroshima et Nagasaki ne sont pas très utiles, les armes d'aujourd'hui étant beaucoup plus nombreuses, puissantes et perfectionnées. L'auteur dépeint un tableau saisissant des effets immédiats de l'explosion d'un engin nucléaire deux milles au dessus d'une ville: le tiers de sa population serait tué et un autre tiers sérieusement blessé avec peu d'espoir de survie considérant l'absence totale de soins médicaux. Et ceci ne serait que le début. Les effets à plus long terme d'une détonation nucléaire — contamination de l'eau et de la nourriture, épidémies dévastatrices, retombées radioactives et disparition des modes de maintien de l'ordre social — réduiraient les survivants au désespoir, les rendant même envieux des "victimes". Finalement, l'auteur examine les effets possibles à long terme de la radioactivité, y compris les cancers dont seraient affligées les personnes exposées, les possibilités de mutations provoquées chez les descendants, et les conséquences biologiques au milieu suite à une contamination prolongée. L'auteur conclut qu'un conflit nucléaire créerait un monde différent, où les causes d'un tel conflit n'auraient plus d'importance.

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Synopsis

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Introduction

At the present time, the fear and dislike that the Warsaw Pact nations and NATO have of each other is greater than the fear that both have of nuclear war. When those fears become reversed, a negotiated, meaningful reduction of nuclear weapons on both sides will be achieved more easily. That is why some attention must be focused upon the terrible effects of nuclear war, even though the task is a disagreeable one.

To impress upon people that the present arms race and current governmental policies are leading us to war; to explain how a nuclear war would be hell on earth; to shut off all avenues of mental escape — no victory, no medical response, no military or civil defence; and to chronicle the dreary story of sickened survivors lapsing into stone-age brutality is not an assignment that any sensitive person undertakes willingly. But unless we contemplate the likely outcome of mankind's present course clearsightedly, and until our leaders confront it realistically, the alternative path of slow, patient, carefully negotiated withdrawal from the brink of the holocaust will seem impossible when, in fact, it is the only route the human race can afford.

The task is also made difficult because one must conjure up the unimaginable and make palpably real events that have never before happened and seem only the stuff of nightmares. The greater we struggle to envision that reality, the more unreal it becomes, and those who construct such images of devastation appear as end-of-the-world hysterics.

There is a further problem. The incredible complexity of all the effects acting, interacting, and interacting again, precludes any confident, detailed presentation of the events in a holocaust. We deal inevitably with approximations, probabilities, even guesses. About all that can be stated with certainty is that our present understanding of the effects of nuclear war probably understates what really would happen because, to the actions and interactions of

consequences that we know would occur, would be added those that we have never even imagined.[1]

It is the uncertainty, the incredibility and the dismal portent of this message, then, that generate resistance and criticism. It is so much easier, so much more comforting to believe the claims that nuclear deterrence and balanced arms will continue to prevent war; or to hope, vaguely, that if the holocaust does happen, it really won't be so bad.

Thus, the motive for this paper is not to sow despair, but to make manifest the true significance of finding alternatives to the nuclear arms race and deterrence: such options are not merely desirable, they are imperative, however difficult their realization may appear.

I. The Failure of Historical Aualogies

Before examining the details of those effects, a sense of perspective is needed. It is only natural that, in trying to imagine something that has never happened in the history of mankind, we should reach back in our collective memory for something analogous to act as a guide. But, in the case of nuclear war, the gap between our past and what could prove to be our future is so great that we must start by disabusing ourselves of the idea that nuclear war would be merely an extension or multiplication of the effects of past wars and disasters.

Since the bombs dropped on Hiroshima and Nagasaki in August 1945 furnish us with the world's only experience of atomic explosions over populated areas, we are obliged to draw heavily on studies of those events.[2] But it is also important to appreciate the limitations of that experience for constructing a picture of what would happen in an all-out nuclear war. The most obvious difference is that those explosions, three days apart, were isolated events. They offer no information on the cumulative effects on society, or on the environment, of hundreds or thousands of such weapons exploding in countries all across the northern hemisphere.

Similarly, the quantitative effects of even a single bomb are also, now, quite different. The Japanese explosions, in the range of fifteen to twenty

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[1] J. Schell, *The Fate of the Earth* (1982) 23 *et seq*. The first chapter of this book is the most comprehensive treatment of the effects of nuclear war for the general reader presently available in English.

[2] The standard work is, Committee for the Compilation of Materials on Damage Caused by the Atomic Bombs in Hiroshima and Nagasaki, *Hiroshima and Nagasaki: the Physical, Medical and Social Effects of the Atomic Bombings* (E. Ishikawa & D. Swain, trans 1981).

kilotons, are only slightly above the level of what are now regarded as "tactical" weapons — up to ten kilotons — and designed for use on the battlefield. Today a city of comparable size, of 300,000 to 400,000 inhabitants, would be targeted with a bomb fifty to seventy times larger (one megaton), while a larger population centre, of say two million or more, would undergo an attack equivalent to two hundred Hiroshimas (three to five megatons).

A different way of expressing the quantitative differences is to compare these modern nuclear weapons to the amount of TNT that would produce explosions of equivalent force. To generate the same power as a one megaton bomb, for example, it would require a million tons of TNT. To ship that much high explosive by rail, it would require a train two hundred *miles* long. A five megaton weapon represents more explosive power than all of the bombs used in the five years of World War II. And some nuclear weapons contain above twenty megatons of explosive potential, more than all of the explosives used in all of the wars in the history of mankind. Indeed, the present arsenals of the United States and the Union of Soviet Socialist Republics are so vast that they represent a million Hiroshimas.[3] If an explosion equivalent to one Hiroshima bomb went off every hour, twenty-four hours a day, seven days a week, it would take almost 115 years to detonate all of the nuclear explosives presently stockpiled by the two superpowers.

The difference in scale between the Japanese experience and anything that would happen now in a nuclear war, even the detonation of one bomb, is fundamental. But there are other differences as well. Simply because today's bombs are so much larger, for instance, there are qualitative as well as quantitative differences. In any nuclear weapon, detonation is associated with the release of radioactivity directly over the area around ground zero. In the case of Japan in 1945, many survivors were exposed to this "immediate" radiation, as it is called. The result for some was radiation sickness and even death. For others, it was leukemia and cancer in later years. With the size of current nuclear warheads, however, everyone exposed to immediate radiation would be killed by the blast and fire. Almost all the radioactive damage done to those still alive would come, not from immediate radiation, but from fallout in the hours following the attack.

In Japan, because the bombs were detonated in the air, there were few heavy radioactive particles settling back to earth in the vicinity of the explosion. As a result, most of what we know about the effects of "local" fallout, as

[3] Barnaby, *The Effects of a Global Nuclear War: The Arsenals* (1982) 11 Ambio 76, 78. This special double issue has many articles, all of them devoted to, in the words of the Editors, "a realistic assessment of the possible human and ecological consequences of a nuclear war".

this regional form that falls within the first day is called, arises from accidents that occurred after World War II, in atmospheric testing done in the United States and South Pacific.[4]

In a future war, population centres would likely suffer air bursts, as in the Japanese case, and therefore would also not experience significant local fallout from such attacks. But, unlike the experience of 1945, most military, and some energy targets such as nuclear power generators, would be subjected to ground bursts and it is these explosions that would send elouds of highly radioactive dust to rain down on cities even hundreds of miles away.

In fact, nuclear explosions on nuclear reactors are a good example of an event which has no precedent in history. The effects of the worst possible accident in a nuclear reactor by itself are minuscule by comparison with those of even a one megaton nuclear explosion. But a nuclear attack on a nuclear reactor would give rise to lethal doses of radiation to exposed persons 150 miles downwind and would produce significant levels of radioactive contamination of the environment more than 600 miles away. Moreover, the radioactivity would be particularly long-lasting. For example, a year after such an explosion, 680 square miles would still be uninhabitable because of sickening levels of radiation.[5]

We also cannot extrapolate from the Japanese experience any information about the effects of long term global fallout. Such fallout would be produced by thousands of megatons of nuclear explosives, particularly air bursts, carrying radioactive particles high into the stratosphere. Here they would spread around the world, particularly, but not exclusively, in the latitudes where the detonations occurred, and would fall gradually to earth over the ensuing months and years. Again, some insight into these problems has been gained through atmospheric tests, but only in so far as the detonation of single bombs is relevant to a massive barrage of explosions around the world.[6]

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[4] See R. Conard *et al., A Twenty-Year Review of Medical Findings in a Marshallese Population Accidentally Exposed to Radioactive Fallout* (1975). For a discussion of testing done in the U.S., see Lyon, Klauber, Gardner & Udall, *Childhood Leukemias Associated with Fallout from Nuclear Testing* (1979) 300 New Eng. J. Med. 397; and Caldwell, Kelley & Heath, *Leukemia Among Participants in Military Maneuvers at a Nuclear Bomb Test: A Preliminary Report* (1980) 244 J.A.M.A. 1575.

[5] See Fetter & Tsipis, *Catastrophic Releases of Radioactivity* (1981) 244 Sci. Am. 41, 45.

[6] See Machta & Telegadas, *Radioiodine Levels in the U.S. Public Health Service Pasteurized Milk Network from 1963-1968 and Their Relationship to Possible Sources* (1970) 19 Health Physics 469. Some attempt to estimate the cumulative effects of all atmospheric testing has been made by the United States National Academy of Sciences, *infra*, note 7.

Finally, the potential for other environmental effects has been appreciated fully only in the 1970s when new insights about the intricate ecological mechanisms that make up the earth's biosphere have been applied retroactively to what was learned previously about the physical effects of individual nuclear explosions during the years of atmospheric testing.[7] New questions have thus arisen and further studies are now in progress.[8]

Anyone who studies the question of the medical and biological effects of nuclear war realizes that it is not a static picture, constructed many years ago and still being sustained by repetition. Rather, it is an actively growing field of inquiry and education. With only one possible exception,[9] all of the expanded knowledge has promoted the realization that the effects would be worse, much worse, than previously thought.

The situation that mankind faces presently, then, has not only been *made* more critical by the proliferation and sophistication of nuclear weapons, it has also been recognized to be more critical as more of the manifold effects of a nuclear war have come to light. This trend toward increased knowledge will continue, but we have almost reached the point where, just as the proliferation of more and more weapons has become redundant, so too will the proliferation of our knowledge of effects. Once it becomes clear that all hope for twentieth century man is lost if a nuclear war is started, it hardly adds any meaningful knowledge to learn of additional effects. Already many students of the subject regard the short term effects as so utterly devastating that they see little point in studying the longer term of a world already blighted beyond repair.

II. Immediate Effects of Nuclear Detonation

What then are the effects?[10] The immediate ones are best imagined by thinking of the consequences of a one megaton explosion detonated, as it would be, roughly two miles above a city. Unlike chemical explosives, a

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[7] See National Academy of Sciences, *Long-Term Worldwide Effects of Multiple Nuclear Weapon Detonations* (1975).

[8] For the most recent information, see articles in Ambio, *supra*, note 3.

[9] *I.e.* the possibility of genetic damage to offspring arising from exposure to radiation by the parents. See also *infra*, Part IV.

[10] The standard authority on the physical effects of thermonuclear explosions is S. Glasstone & P. Dolan, *The Effects of Nuclear Weapons*, 3d ed. (1977) (a publication of the United States Dep't of Defense and the United States Energy Research and Development Administration). See also Congress of the United States, Office of Technology Assessment, *The Effects of Nuclear War* (1979), which, as its title suggests, applies the knowledge of these effects to likely war situations. A systematic account of the effects on a single large city can be found in O.

thermonuclear weapon has three important effects — blast, thermal and nuclear radiation. These occur almost simultaneously, but, for simplicity's sake, are usually described separately.

Out of the bright fireball, in which the temperature and pressure are the same as those at the centre of the sun, a blast front or concussion wave moves out in a widening circle at supersonic speed, followed by high winds. Within a two mile radius of ground zero, nothing can withstand this blast or the 500 mph winds that follow. Even at four miles, only the skeletons of buildings with I-beam construction would remain, the following winds still having twice the velocity of a hurricane. Out to eight miles from the centre, large commercial buildings would be damaged heavily and all homes destroyed. Up to twelve miles, the concussion would be great enough to shatter glass, and send the splinters flying off at over 100 mph. At this distance, damage to homes would be significant but they could probably continue to provide shelter.

Even before this blast front, however, there would be a heat wave radiating out from the fireball at the speed of light igniting spontaneously everything inflammable within a three to five mile radius. Ten miles away this thermal radiation is still severe enough to cause second degree burns to exposed skin. At thirty miles, a person who happened to focus his gaze at the spot just as the detonation occurred would suffer retinal burns and possibly blindness.

In a typical explosion, about half of the energy is released as blast and another third as thermal radiation. The remainder, roughly fifteen *per cent*, is released in the form of nuclear radiation. But, as has been said, those who have been exposed to immediate radiation from today's larger weapons do not survive the blast and heat. The rest of the radiation occurs as fallout which can be discussed more appropriately after this description of the immediate effects is concluded.

Mortality within the first two mile radius is essentially one hundred *per cent* and almost entirely instantaneous. Even out to four miles, it is fifty *per cent*, another forty *per cent* being injured seriously. At eight miles, half the population would be dead or injured and at twelve miles, a quarter would be injured, some seriously, by flying glass and debris. People can withstand concussion much better than rigid buildings, but in a city this fact has little

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Greene, B. Rubin, *et al.*, *London After the Bomb* [:] *What a Nuclear Attack Really Means* (1982). Medical considerations are detailed in R. Adams & S. Cullen, eds, *The Final Epidemic* [:] *Physicians and Scientists on Nuclear War* (1981); and E. Chivian, S. Chivian, R. Lifton & J. Mack, eds, *Last Aid* [:] *The Medical Dimensions of Nuclear War* (1982).

relevance. Death and injury occur not so much from the explosion itself but from the fact that it turns people and debris into projectiles that hurl into stationary objects and into each other. Multiple fractures, puncture wounds and the smashing of skulls, limbs and internal organs makes the list of possible injuries endless. But the special horror of nuclear war, so far as immediate effects are concerned, is flesh-cooking heat.

In the central area, total devastation is combined with incineration. Nothing is left. But beyond this perimeter of annihilation, what is striking about survivors is that, whatever injury they may or may not have sustained from the physical blow, the great likelihood is that they are burned seriously. Third degree burns, even to protected skin, can occur within three miles and, to exposed flesh, within five. Burns can also occur secondarily. At Hiroshima, the hundreds of fires started by thermal radiation coalesced within twenty minutes into a raging fire storm. This is a giant, self-feeding bonfire in which the updraft sucks powerful surface winds toward its centre thereby fanning the flames of the ever-widening perimeter. Temperatures can reach 800 degrees celsius — almost 1,500 degrees fahrenheit. Anyone in the area, even if in a shelter, is either incinerated by the intense heat, asphyxiated by the lack of oxygen which is consumed instead by the flames, or suffocated by the lethal doses of carbon dioxide that are released. An alternative result of many small fires would be a conflagration in which a wall of flame, fanned by prevailing winds, advances in one direction on a wide front. Under certain conditions, either sort of fire, fire storm or conflagration, could lead to a destructive force that would kill more people than the initial effects of the bomb.

The likelihood of either of these events is disputed however. With bigger bombs, there is a time lag between the heat wave and the ensuing concussion and winds. This could mean that the fires started by the thermal pulse would be snuffed out by the following blast. Moreover, it may be that the density of inflammable materials in modern cities is not sufficient to generate or sustain such mammoth fires. Because only a nuclear expolsion over a modern city could resolve the debate, it is to be hoped that the controversy remains academic.

In any event, the number of severely burned survivors would be very large. In Hiroshima, where there was a fire storm, it is estimated that half of the early deaths resulted from burns. So far as immediate effects upon people are concerned, it is the high proportion of severe burn cases that distinguishes injuries from a thermonuclear attack from those of other kinds of warfare.

This fact can serve to illustrate another consequence of nuclear war — the hopelessness of counting upon medical services in the post-attack period. Burns present special medical problems. They are particularly painful; their victims especially helpless; their medical needs urgent; and the outcome, in

terms of life or death, more dependent on the medical and nursing care given than most other conditions. But most of all, the care of burns requires some of the most sophisticated and specialized equipment and personnel that modern medicine can provide. In fact, so expensive and specialized is this form of care, that facilities are scarce, even at the best of times. For example, Montréal, a city of over two million people, presently has facilities for six severe burn cases. There is talk of expanding these facilities but, even at a cost of $1.5 million, there would only be twelve such beds. In fact, for the whole of North America, there are estimated to be approximately 2,500 beds for serious burn cases. Yet, if a one megaton bomb were exploded over Montréal, there could be as many as ten thousand people requiring such facilities. The final irony is that those six beds in Montréal are located in a hospital within three miles of the city centre — which would almost surely be destroyed in the initial explosion.

This example reveals two aspects of the medical reponse to nuclear attack which, when combined, make any meaningful help an impossibility. One fact is that the number of casualties would overwhelm the locally-available medical services even if these were intact. The other is that they would not be intact. In most modern cities, there tends to be a concentration of medical facilities and personnel in the city centre, particularly the large hospitals and sophisticated equipment and specialists that would be required by many of the badly injured survivors. In the example of Montréal again, about eighty *per cent* of its medical facilities are within a five mile radius of the city centre and eighty *per cent* of these facilities could be expected to be rendered inoperative by a single, one megaton warhead. In fact, given the special population distribution of Québec, it seems that fifty *per cent* of all the practising physicians in the province have their offices within this five mile circle.

In the first twenty-four hours, then, the immediate effects of a one megaton bomb would be to leave a circle of damage twenty-five miles in diameter in which an inner core, fifteen miles wide, would be more or less totally destroyed. At least a third of the population would be dead, another third seriously injured, many of these dying in the days ahead, in part because of a total lack of medical assistance. But a city such as Montréal would not escape so lightly. One official estimate suggests that a city of this size would be attacked by two to five megatons.[11] In this case, the city and the countryside around would be simply obliterated. But that is only the beginning.

[11] Emergency Planning Canada, *Planning Guidance in Relation to a Nuclear Attack on North America in the 1980's* (1981) (document EPC 2/81).

III. Longer Term Effects of a Nuclear Detonation

Any country that suffered from a determined nuclear attack on its cities, military installations and energy production would have to contend with a great deal more in the days and weeks that followed. The loss of communications, transportation, electricity, and other social utilities; the absence or scarcity of uncontaminated food and water; the heavy burden of the sick, injured and mentally incapacitated; and the disappearance of the instruments of social organization and social order would create chaos for the relatively healthy survivors and would make their situation as desparate as that of those less "fortunate".

As if this were not enough, there would be the additional problem of "local" radioactive fallout that would settle back to earth over the first twenty-four hours in the form of relatively heavy particles or dust, raised by ground bursts and carried by the winds. Because the speed and direction of the wind in a given location can vary enormously over the seasons, days and even hours, just where and how far such radioactivity would spread is wholly unpredictable. Moreover, weather conditions, especially the presence or absence of preciptation, as well as features of the terrain, would make the actual distribution erratic.

For the sake of illustration, these variables are often taken as uniform for the twenty-four hours during which fallout would occur. For example, after a one megaton ground burst, if the wind blew steadily in the same direction at fifteen mph, a long cigar-shaped plume of radioactive dust would be laid down, assuming no rain and perfectly level ground. People inhabiting this region would then be subjected to the radiation given off by this fallout. The amount that a person would receive would decline rapidly — less rapidly if a nuclear reactor had been struck — but the exposed individual would be accumulating biological damage as long as he remained exposed.

In this example, it can be calculated that, over a two week period, any person who lived within roughly 700 square miles downwind of the blast, that is to say anyone in an area about 80 miles long and 11 miles wide, would receive a potentially lethal dose of radiation unless he remained specially sheltered for that length of time. Someone living within a band 19 miles wide and 175 miles long would need to take some precautions for most of that time in order to avoid radiation sickness. And people in a strip 45 miles wide and 440 miles long, an area of more than 14,000 square miles, would be living on land contaminated with long-lasting radioactive particles that could be inhaled in the air they breathed or incorporated in the food they ate for the rest of their lives.[12]

[12] The area covered is not a rectangle. Hence it is less than the product of length times width. For a comprehensive discussion of all aspects of radiation, see J. Rotblat, *Nuclear Radiation in*

Most of the industrialized nations of Asia, Europe and North America that would suffer attacks in a nuclear war thus would undergo an initial, devastating blow that would produce death, injury and social chaos on a scale unprecedented in human history. Then, within twenty-four hours, much of that same territory would be blanketed with radioactive fallout, much of it with serious short term consequences and all of it potentially hazardous for years to come.

Against this background, how can anyone guess the course of events over the weeks and months that follow an attack? For example, assuming that only half of the megatons in the current United States and Soviet arsenals were detonated, one scenario estimates that, of the 1.3 billion people in the cities of the northern hemisphere, there would be 750 million immediate deaths, 340 million seriously injured and 200 million "healthy" survivors.[13] This might lead one to suppose, for instance, that short term food supplies would be abundant. But this overlooks completely the dependence of modern societies on daily food transportation and distribution, and the likelihood of vast quantities being destroyed or rendered inedible. Large numbers of people in some areas probably would starve while stocks of food elsewhere would rot.

A more specifically medical problem would be the appearance of devastating epidemics. The various glands and organs of the body that provide natural immunity against infection are particularly sensitive to radiation. When combined with social disintegration, this would invite the rapid spread of communicable diseases in unusually severe forms.[14]

Today in the industrialized world, diseases such as the plague, smallpox, cholera, and typhoid fever have been relegated, we assume, to the history books. We commonly think that we have banished their microbes, or can fight them so effectively that rare cases cannot fuel a general epidemic. But, in truth, it is the affluence and orderliness of our society — ample nutrition, sanitation and immunization programmes, as well as the immune systems of our own bodies — that hold these diseases at bay. After a nuclear war all these defences would be compromised severely; they may even be non-existent, along with the medical services and supplies needed to treat the cases that did appear.

For example, it has been estimated that as much as three-quarters of the United States population is no longer protected adequately against smallpox

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Warfare (1981) (a SIPRI monograph). This information is applied to the effects on a specific country in Bates, Briskin, *et al.*, "What Would Happen to Canada in a Nuclear War?", in E. Regehr & S. Rosenblum, eds, *Canada and the Nuclear Arms Race* (1983) 171.

[13] Middleton, *Epidemiology* [:] *The Future is Sickness and Death* (1981) 11 Ambio 100, 102.

[14] See Abrams & Von Kaenel, *Medical Problems of Survivors of Nuclear War: Infection and the Spread of Communicable Disease* (1981) 305 New Eng. J. Med. 1226.

because the odds of suffering ill effects from vaccination, although very low, are nonetheless higher than the odds of catching smallpox, which are practically zero. The virus is stored in disease control centres, in case a vaccine has to be made. These centres exist in areas likely to suffer a nuclear attack. If the germs escaped into the community, would there be facilities left to produce vaccine? Would there be transportation to distribute it? Would the health services be able to vaccinate people? Would the immune systems of hundreds of thousands of radiated victims respond sufficiently to furnish protection? And would all this take place before an epidemic of smallpox decimated the survivors? Whatever happened, one thing is certain: bacteria, viruses and insects are highly resistant to radiation. An all-out nuclear war could tilt the favourable balance of nature from humans to bugs.

And what would twentieth century citizens of the industrialized world do in the absence of any industrial base, any capital to rebuild it, or any energy source to run it?

> The task... would be not to restore the old economy but to invent a new one, on a far more primitive level. ...The economy of the Middle Ages, for example, was far less productive than our own, but it was exceedingly complex, and it would not be within the capacity of people in our time suddenly to establish a medieval economic system in the ruins of their twentieth century one. ...Sitting among the debris of the Space Age, they would find that the pieces of a shattered modern economy around them — here an automobile, there a washing machine — were mismatched to their elemental needs. ...[T]hey would not be worrying about rebuilding the automobile industry or the electronics industry; they would be worrying about how to find non-radioactive berries in the woods, or how to tell which trees had edible bark.[15]

A final question is: Would the numbers, physical health and reproductive capacities of the survivors, combined with the social and natural environment, be adequate for the continuation of the human species, let alone for its eventual restoration to something akin to civilization? Of course, no one can answer this question. And no amount of scientific enquiry is ever likely to decide the matter beyond dispute. All that can be done is to speculate on the basis of the information we have.

To make the question easier, it can be considered in two parts. Suppose, first, that no important, long-lasting, deleterious effects were inflicted on the natural environment of half of the world's land mass. Would mankind survive? Surely the answer is — yes. For even if humans died out throughout most of the northern hemisphere it is not likely that the southern half would suffer the same fate. Of course, it is quite possible that some, even several, targets in the south would be attacked.[16] And, in any event, the collapse of the

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[15] Schell, *supra*, note 1, 69 *et seq.*

[16] See *ibid.*, 71 *et seq.*; and Barnaby, Rotblat, *et al.*, *Reference Scenario: How a Nuclear War Might be Fought* (1982) 11 Ambio 94, and appended maps.

economies of the north, along with their food-producing capacities, would trigger massive starvation and political turmoil throughout the developing and undeveloped countries of the Third World. But it remains difficult to imagine that if large areas of cultivable land remained, and the environment continued to sustain crops and human habitation, that man, agricultural man, would not survive. Nuclear war might undo, for a considerable time, the industrial revolution of the eighteenth and nineteenth centuries, but it would not reverse the agricultural revolution of 10,000 B.C.

What would be critical, therefore, would be the second part of the question — the long term, life-supporting capacity of the natural environment. At this point, conjecture becomes so large a part of the assessment that completely contradictory effects may be postulated. For example, in a 1975 report, the United States National Academy of Sciences raised the question of damage to the stratospheric ozone layer which shields the earth from a biologically damaging range of ultra-violet rays from the sun.[17] The premise for this calculation, however, was that of a large number of nuclear weapons in the one to five megaton range. A recent study, using a more sophisticated model of the same scenario, concurs broadly with these findings. But, using a different premise, reflecting recent changes in nuclear weaponry, the same study postulates very different results. In the latter case, weapons chiefly in the range of 100 to 500 kilotons are presumed to constitute the major mode of attack. When this model is assumed, the *reduction* of ozone in the stratosphere is not significant but its *production* in the trophosphere is increased, thereby producing, along with particulate matter and chemicals from many fires, a large amount of photochemical smog.[18]

In either scenario, however, the final result could be the same — crop failures inducing large scale famine among survivors. This famine would depopulate the world further, especially the northern hemisphere. But, beyond this, the atmospheric, ozone effects would not be sufficiently long-lasting to have an impact upon succeeding generations.

Alterations of regional weather patterns and larger scale changes of climate caused by nuclear explosions are conceivable but not presently predictable with any confidence. Moreover, it is not possible to say whether any changes that might occur would persist to affect generations beyond that of the survivors. Predicting such global changes, and their evolution over many decades, requires accounting for a multitude of interacting variables, a task that presently overwhelms the capacities of a field of study that is still in its infancy.

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[17] *Supra*, note 7.

[18] See Crutzen & Birks, *The Atmosphere After a Nuclear War* [:] *Twilight at Noon* (1982) 11 Ambio 114, 121.

IV. Long Term Effects of Nuclear Radiation

Finally, there is the question of the long term effects of nuclear radiation. This question should actually be broken down into two: the long term effects of short term exposure to high doses from local fallout in the days immediately following the nuclear exchange; and, the effects of continuing long term exposure to low doses arising from the long-contaminated environment.

Our chief source of evidence regarding the first issue is the experience of Hiroshima and Nagasaki. The impact of short term high doses would be severe on the surviving generation. Death, radiation sickness or the radiation-enhanced severity of wounds, burns and infections would be the short term results. Miscarriages, still births or birth defects like microcephaly and mental retardation would be the lot of the fetuses of exposed pregnant women. Epidemic levels of leukemia, especially in children, would appear in five to ten years. Cataracts and temporary sterility would afflict many. Excessive numbers of cancers would plague the exposed populations for the rest of their days. But whether or not they would, through genetic damage, pass on this blight to generations conceived after the war is still a matter of controversy. The evidence from Hiroshima and Nagasaki is equivocal as yet, and whatever the eventual results, that experience simply may not be relevant to the conditions of a modern, all-out nuclear war.[19]

The experience of 1945 also tells us little about the effects of short term, high dose exposure when combined with long term, low dose exposure, a combination that did not occur then but that certainly would in any future nuclear exchange. The long term presence of low dose radiation would come from two sources: local fallout that would be distributed in "plumes" over areas downwind from ground bursts as has been described above; and global fallout coming down everywhere, from the stratosphere, over months and years.

In either local or global fallout, the most important substances are strontium-90 and cesium-137 because their radioactivity decays so slowly that, in about thirty years, half of the material is still radioactive. Moreover, by a complicated biological chain from soil to plants to animals to man, these substances become incorporated in the human body; strontium, through milk and meat, accumulates in bone; cesium, through fish, vegetables and other plants, is taken up by soft tissues. From *foci* of concentration within the body,

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[19] See Schull, Otake & Neel, *Genetic Effects of the Atomic Bombs: A Reappraisal* (1981) 213 Science 1220. See also an editorial by Neel, *Genetic Effects of Atomic Bombs* (1981) 213 Science 1205. Among the ways in which the Japanese experience may not be applicable is in the sheer number of subsequent matings where *both* parents have suffered from exposure to radiation.

doses of beta-rays and gamma-rays can eventually be built up that are harmful to nearby tissues and organs.

More insidious still, plutonium, chiefly in the form of plutonium-239, would also be a contaminant because it is used in the trigger of nuclear weapons, is produced in the explosion and is also present in nuclear reactors. This substance has a half-life of 24,400 years. Its radioactivity is in the form of alpha particles that have almost no pentrating power. But plutonium-contaminated dust can be inhaled and deposited in the lungs where a sufficient dose can induce lung cancer.

The heaviest burden of long term, low level radiation would, of course, fall upon the surviving generation. And while, through early death, relative infertility and other effects, that generation's capacity to reproduce and to provide for the next generation would most certainly be compromised, it is clear that this factor alone — radiation — would not be a sentence of death for the whole human race in the way that Nevil Shute imagined in his novel *On The Beach*.[20] In Japan, excess deaths from cancer, for example, are occurring in age ranges that are typical for the same cancer caused by other means, regardless of the amount of time since exposure. If this holds true, most cancers would appear after the age of reproduction. And, while there would be obvious and measurable effects on the next generation through their own exposure to the continuing presence of radioactive contamination, this factor alone would not be likely to lead to the disappearance of the human race.

What we cannot predict, though, and perhaps never will with any confidence, is the impact of many ill effects working in combination on man and nature. As with other animals, there may be a minimum number of humans required to drive the population dynamics in the direction of growth rather than extinction. A combination of population thinning through immediate decimation, the subsequent ravages of disease, famine and social disorder, relative infertility and shortened life spans, and a climatically unsupportive environment conceivably could push man into the position of an endangered species. Moreover, the fact that no catastrophic and terminal effect on the life supporting capacity of the biosphere has yet been proven should not diminish our awareness of the possibility that this could occur and that human life on earth could come to an end fairly quickly on this basis alone.

[20] N. Shute, *On the Beach* (New York: Morrow, 1957). But the superpowers are working on it. See Feld, "Mechanics of fallout" in Adams & Cullen, *supra*, note 10, 110, 115.

Conclusion

This survey of the medical and ecological effects of an all-out nuclear war is by no means complete. Rather, it has been an attempt to give some idea of the state of present knowledge on the subject, with particular attention to the long term, large scale trends. The best information we currently possess suggests, not surprisingly, that the physical impact of nuclear exchanges would be greatest in the first minutes to hours after the war started. But, unlike in previous conflicts, the physical damage and the biological consequences could continue, at first with severity, but then at a lower level, for many years. The result would be catastrophic for the surviving generation, but an impact would be felt, though with decreasing severity, over the next generation or two at the very least.

But when all is said and done, most of the effects that have been discussed would be but the physiological and enviromental substrata to the real impact of a nuclear war — the economic, social and cultural destruction of modern, industrialized society. Nuclear war would represent a turning point in human history, more sudden and more drastic that anything that has gone before. Just where it would turn us, and just what it would portend for the future of humanity and civilization is impossible to predict. But one effect would surely be that a very different world would emerge, a world in which the values, ideologies and struggles for power that had caused the war in the first place would have become simply irrelevant.