GUEST EDITORIAL

Environmental Consequences of Nuclear Warfare*

The Earth has yet to experience a large-scale nuclear war, with its immense and diverse energy-releases, so that predictions of environmental impact must to a considerable extent remain speculative. The difficulties of such predictions are compounded by our not knowing the total numbers, types, yields, and locations, of the nuclear detonations in a possible major war between the superpowers. Nevertheless, studies of the Hiroshima and Nagasaki attacks, of our numerous test-explosions, of natural catastrophes, and of theoretical considerations, permit us at least to suggest the possible extent of the environmental impact of such an event (Nier *et al.*, 1975; Westing, 1977, 1978, 1981, 1982; ACDA, 1978; Thunborg *et al.*, 1981).

The energy-releases of primary environmental concern are blast, heat, and nuclear radiation. I shall devote some brief consideration to each of these in turn, before discussing some of the potential second-order effects of ecological concern.

Blast-energy Effects

A nuclear bomb dissipates roughly half or more of its tremendous energy in the form of a shock- or blast-wave. The blast is responsible for much of the immediate physical damage brought about by nuclear explosions. Thus a single one-megaton airburst would knock down virtually all of the trees over some 14,000 ha and, additionally, force thousands of tonnes of the water vapour (humidity) present in the lower atmosphere (troposphere) into the upper atmosphere (stratosphere). On the other hand, a single one-megaton groundburst would blast out a huge crater, extending over perhaps 12 ha and with a maximum depth of some 90 m. An estimated 50,000 tonnes of the rock and soil thus displaced would be hurled into the upper atmosphere as a fine dust. A single one-megaton underwater burst would lift tens of thousands of tonnes of water aerosol and vapour into the upper atmosphere.

Heat-energy Effects

A nuclear bomb dissipates roughly another one-third or more of its energy in the form of an intense thermal or heat wave. This heat would initiate wildfires over an immense area, the exact size of which would depend, of course, upon the weather conditions at the time, the terrain, and the nature of the vegetative cover. Indeed, under certain terrain and fuel conditions these fires would coalesce into a truly infernal firestorm. On a clear, dry summer day a single one-megaton airburst might well initiate wildfires throughout an area of more than 32,000 ha, and these would be likely to continue to burn and spread for weeks. These fires would wreak havoc among the plants and animals surviving the blast and nuclear radiation. They would also inject immense amounts of smoke into the atmosphere.

The surface disruption from blast and fire would in turn lead to massive site-degradation of long duration (i.e. decades) from soil erosion and nutrient losses in solution (so-called nutrient dumping). Moreover, the exceedingly high temperatures momentarily generated by a single one-megaton airburst would result in the transformation of some 5,000 tonnes of the atmosphere into various oxides of nitrogen. These oxides of nitrogen would in turn produce a smog in the lower atmosphere and degrade the ozone in the upper atmosphere, thus attacking a molecule which forms a protective barrier against excessive solar ultraviolet radiation.

Radiation-energy Effects

A nuclear bomb dissipates the remaining 10% or so of its energy in the form of nuclear radiation, a portion of which is released as an initial burst and the remainder—in the form of radioactive fallout—much more slowly and widely. A single one-megaton groundburst would present a lethal dosage of nuclear radiation to all exposed vertebrates (including, of course, humans and livestock) over about 36,000 ha. As a specific example I might cite the 'Bravo' test at Bikini on 1 March 1954—a single 15-

* Based largely on the Author's testimony before the US House of Representatives, Committee on Science and Technology, Subcommittee on Investigations and Oversight, Washington DC, 15 September 1982, and recalling our stressing of this horrific topic with Professor Westing's help in our Winter issue of last year.—Ed.

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megatons groundburst—which deposited a lethal level of fallout over an area approximately the size of the State of Massachusetts. Moreover, although the test programme on Bikini ended more than a quarter of a century ago, the island remains uninhabitable despite intensive cleanup attempts. It must also be noted here that, in a war, some of the hundreds of stationary or mobile (naval) reactors and the like would almost inevitably be hit and the thereby-dispersed radioactive debris would increase the extent of the regions of death to flora and fauna, and of uninhabitability to humans.

Longer-term Synergistic Effects

The several forms of intense energy released during a nuclear war that I have just summarized, would leave large areas of appalling devastation to Man and Nature even from single or small numbers of nuclear detonations. However, I wish to devote the remainder of this presentation to the possibility that a large-scale exchange of nuclear weapons could result in longer-term synergistic second-order effects on The Biosphere. Thus, the total effect of many bombs will almost certainly be greater and more multifarious than a mere summation of the effects of each individual bomb would suggest; and, moreover, some of these effects would surely come upon us as a surprise.

Among the potentially disastrous phenomena that we can guess at would be those which are set in motion by the large-scale injection of fine particles of dust and water into the upper atmosphere, by the generation of vast quantities of smoke and smog, and by the introduction of huge amounts of oxides of nitrogen into the ozone layer. Of these the first, namely dust and water in the stratosphere, could have long-term adverse effects on our climate (Nier *et al.*, 1975), while the second, smoke and smog in the troposphere, could for a time (i.e. for perhaps one or even two growing-seasons) substantially reduce the primary productivity of ecosystems and debilitate our agriculture (Crutzen & Birks, 1982); and the third, a depleted ozone layer, could permit damaging ultraviolet radiation to reach the Earth's surface as will be developed more fully below.

It is not at all certain either how much of the protective ozone layer would be destroyed by a large-scale nuclear war or how long it would take for the ozone layer to return to its normal state of equilibrium. One major study carried out several years ago by the US National Academy of Sciences suggested that an amount of the order of half (30% to 70%) of the ozone would be destroyed, and that substantial recovery would take up to a decade (Nier *et al.*, 1975). More recent, as yet unpublished, estimates at the Massachusetts Institute of Technology suggest that these values might well be optimistic (Kosta Tsipis, pers. commun. April 82). However, the uncertainties involved are so intractable (both as regards the input data and the models) that it becomes almost silly to argue over the magnitude of these values. Using a 50% depletion of several years' duration as our starting-point, however, we find that this would lead to a substantially increased fraction of solar ultraviolet radiation reaching the Earth's surface—perhaps a threefold increase in the biologically active portion, which is in the wavelength range of approximately 280–380 nanometres, the so-called UV-B range (Gerstl *et al.*, 1981). It must be added here that this effect would be world-wide even if the war should be confined to portions of the northern hemisphere—owing to the world-wide lateral dispersion of the ozone layer by diffusion in the lower stratosphere.

Grave Impact on Ecosystems

The ecological impact of enhanced UV-B radiation on various natural and artificial ecosystems—oceanic, terrestrial, or agricultural—cannot be predicted with any certainty, but could be devastating on a global basis (Nier *et al.*, 1975; Tukey & Peters, 1979; Crutzen & Birks, 1982; Kruger & Setlow, 1982).

Oceanic ecosystems would be substantially disrupted on a global basis by the enhanced UV-B radiation following a large-scale nuclear exchange (Tukey & Peters, 1979; Calkins & Thordardottir, 1980; Jokiel, 1980; Worrest *et al.*, 1981*a*, 1981*b*; Kruger & Setlow, 1982). Marine plankton lie close to the surface of the ocean, and if they were killed-off to a substantial extent, the oceanic food-chain would be largely broken and the fish stocks which depend upon this chain would be placed in jeopardy. As the ozone effect is global (and adds to that of the pall of smoke and smog), repopulation might take a number of years, and would thus be unlikely to be rapid enough to save a major fraction of the many plankton-dependent species. The restoration of fish-stocks throughout the world (both commercial and otherwise) might thus in turn take many years to occur.

Terrestrial ecosystems would also be substantially disrupted on a global basis by the enhanced UV-B radiation following a large-scale nuclear exchange (Nier *et al.*, 1975; Faber *et al.*, 1979; Tukey & Peters, 1979; Caldwell, 1981; Kruger & Setlow, 1982). This seems evident because extrapolation from the limited

information available indicates that perhaps as many as 20% of the world's plant species might succumb either directly or indirectly, at least over much of their ranges, and an additional fraction of them would have their photosynthesis (food production) and growth impaired over wide areas. Moreover these debilitations would be added to those of nuclear radiation from fallout (especially in the case of ecosystems dominated by the relatively sensitive conifers), of smoke and smog, and so forth. Such drastic perturbations among the primary producers of the world's ecosystems (including newly-altered relationships of competitive advantage) would in turn exert a substantial impact throughout the world on the wildlife depending upon them. Some of the animal life might also be injured directly by the enhanced UV-B radiation. This seems clear because in most instances the newly-created damaging levels would not be detected by the animals, and this would therefore preclude evasive actions. Thus, for example, unavoidable damage to the cornea of the eye would reduce the efficiency of hawks, eagles, and much other wildlife, in their hunting or foraging abilities.

During the first several years following a major nuclear exchange, agricultural ecosystems would also be severely disrupted on a global basis by the enhanced UV-B radiation (Nier *et al.*, 1975; ACDA, 1978; Tukey & Peters, 1979; Kruger & Setlow, 1982). And again, such damage would compound the problems resulting from radioactive contamination (to which crops, for example, are generally more sensitive than their weedy competitors and their fungal and insect pests), the smoke-and-smog pall (which would reduce productivity both directly and perhaps *via* adverse climatic changes), and the paucity of farm workers, implements, fuel, fertilizers, and pesticides (herbicides, fungicides, and insecticides). Some crops—among them corn (maize), sugar-beets, tomatoes, and various beans and peas—turn out to be especially sensitive to enhanced UV-B radiation, and livestock would develop debilitating corneal and perhaps skin lesions.

In conclusion, it is necessary to stress that my outline of the potential environmental consequences of nuclear warfare are based upon extrapolations from very limited data. My predictions were meant to be conservative ones and thus probably err on the side of optimism. For example, the several diverse impacts discussed separately above would, of course, occur simultaneously and, by reinforcing one another, would be likely to have effects substantially greater than if they had occurred separately. Synergism of this kind is most difficult to predict. I wish additionally to stress that even any single major environmental or ecological perturbation could result in entirely unforeseen ramifications. It is instructive to note here that the potential dangers of enhanced ultraviolet radiation resulting from nuclear war had not been foreseen by military planners, but were recognized accidentally as the result of an unrelated study of supersonic aircraft exhausts. Indeed, if total nuclear war were ever to occur, it would be unrealistic for me to rule out at least the possibility that the impact on The Biosphere would be sufficiently drastic to lead to the ultimate extinction of the human species.

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The Imperative of Disarmament*

You have heard many eloquent arguments in favour of disarmament, but the deliberations of this Assembly have served to show the watching world that in 1982 we are still where we were in 1978—facing the same stark choice of survival or annihilation.

Modern weapons have the deadly capacity not merely to wipe out cities, industries, and even entire populations, but also to destroy the life-giving systems on which we all depend. I am convinced that the need to preserve our shared environment provides the most persuasive argument for nations to stop this dangerously escalating spiral of the arms race.

The peoples of the world do not want war; they want the arms race to be reversed, and they want the danger of nuclear war to be eliminated. They are puzzled and bemused by the present situation—seeing obvious contradictions in the attitude of the world community to the whole question of military activity. On one hand the numerous conventions, treaties, and agreements, provide clear evidence of a widespread desire to prevent the more devastating forms of warfare; but on the other, the evidence of mounting military expenditure around the world implies a lack of conviction in the practicability of disarmament, or even of holding forces and arsenals at a constant size. The peoples of the world look to the United Nations to show how we can achieve the security which the arms build-up has not only failed to provide but has latterly negated to a terrifying degree.

The message, though expressed in a multitude of ways and in many languages, is to *act now*, firmly and thoroughly, and UNEP values this opportunity to be part of the call for action which we see as an urgent imperative for all mankind. For even if the nuclear powers and possessing Governments should behave themselves, we would still have to fear anarchical terrorist gangs.

Recently, as many of you are doubtless aware, UNEP held in Nairobi the 'Session of a Special Character' of its Governing Council†, to mark the tenth anniversary of the Stockholm Conference on the Human Environment. In Nairobi, representatives of 105 Governments were as one in declaring that 'the human environment would greatly benefit from an international atmosphere of peace and security, free from the threats of any wars—especially nuclear war—and the waste of intellectual and natural resources on armaments.' By a special resolution, the representatives of those nations assembled in Nairobi appealed to Governments and the world community as a whole to do their utmost to halt the arms race and thereby prevent a major threat to the environment. They requested the Secretary-General of the United Nations to bring their appeal to the attention of this Special Session of the General Assembly, where it is circulated as document A/S-12/AC.1/16.

The Nairobi sentiment was the same that moved Governments at the General Assembly in 1980 to proclaim the historical responsibility of States for the preservation of Nature for present and future generations, and to request the Secretary-General, with the cooperation of UNEP, to prepare a report on the pernicious effects of the arms race on Nature.

My mission today is, basically, to present to you the report of the Secretary-General on this subject (document A/S-12/9), which is based on the views of Governments, three substantive reports transmitted to Governments, and the conclusions of an expert body convened to examine the replies received to the questions we had put before Governments.

* Based on the statement of the Executive Director, United Nations Environment Programme, to the Special Session of the United Nations General Assembly on Disarmament, delivered in New York, NY, on 21 June 1982.—Ed.

† *See* our account on pages 169–70 of this year's Summer issue of *Environmental Conservation*.—Ed.