Chapter V

OTHER LONG-TERM EFFECTS

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TABLES

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The preceding chapter has made it clear that even the immediate effects of a nuclear attack would have a long-term impact. Structures and resources that would be destroyed in seconds (by blast) or hours (by fire) might not be rebuilt or replaced for years, or even decades. People who would die in seconds or in weeks (from fallout radiation) might not be repiaced in a demographic sense for several generations. Political social, and economic changes arising from the immediate postattack disruption would probably prove in some significant respects to be irreversible.

There is another category of effects of nuclear war, however, which are “long term” in the sense that they would probably not be noticeable for some months, or even years, after the attack took place. Such effects include long-term somatic and genetic damage from radiation, possible changes in the physical environment (including the possibility of damage to the ozone layer of the upper atmosphere), and possible changes in the ecological system of which humans area part. These are effects that conventional weapons cannot produce. They are discussed under three rubrics:

- Effects from low-level ionizing radiation, which are reasonably certain to take place, whose magnitude would depend on the scope of the attack, and which can to some extent be calculated on the basis of existing data and theory.
- Damage to the ozone layer in the atmosphere. Such damage could injure human and animal health, and possibly lead to changes in the Earth’s climate. At the present time it is not known how to calculate the likelihood of its occurrence, but ongoing research into the chemistry of the upper atmosphere offers promise of greater understanding in the future.
- Other effects whose magnitude and likelihood are incalculable, but whose possibility should not be ignored.

CALCULABLE EFFECTS: IONIZING RADIATION

A large body of scientific literature addresses itself to the issue of long-term effects from low levels of ionizing radiation, There has been an intensive study over the years of the health of the survivors of Hiroshima and Nagasaki, and of some of those who were subjected to radioactive fallout as a result of nuclear weapons testing. There has been considerable research into the question of how large a quantity of radioactive particles of various kinds are produced by nuclear weapon explosions. There is a body of theory regarding the effects of ionizing radiation on the human body. But there are also formidable uncertainties. New information is coming to light regarding some of the effects of past weapons testing, and there are unresolved scientific controversies over matters as basic as whether a small dose of radiation does more damage to the human body (or, from a statistical point of view, is more likely to do a given amount of damage to a human body) if it is absorbed during a brief period of time than if it is absorbed over a longer period. There are pertinent questions whose answers are only known to within a factor of 10.

Previous chapters have discussed the effects of very intensive ionizing radiation: 1,000 reins will almost certainly be lethal if absorbed within a matter of days; 450 reins will kill 50 percent of a healthy adult population, and a slightly higher percentage of the young, the old, and those without adequate medical care; 250 reins will cause acute radiation sickness, from which "recovery" is probable; and even lower doses may lower the body's resistance to infectious diseases of various kinds. It is generally assumed that because of the rate at which fallout radiation decays, doses of this magnitude are likely to be received during the first so days after an attack if they are received at all. The preceding chapter, and appendix D, include calculations on the numbers of people who might die from radiation effects during the first 30 days after various kinds of nuclear attack.

However, doses of ionizing radiation that are too small or too slowly accumulated to produce prompt death or radiation sickness nevertheless have harmful effects in the long run. These effects can only be discussed statistically, for it appears that if a large population is exposed to a given (small) dose of radiation, some will suffer harmful effects while others will not. The larger the dose, the greater the percentage of the population that is harmed, and the greater the risk to any one individual.

There are a number of ways in which a nuclear attack would lead to radiation exposures which, although too low to cause death within the first 30 days, nevertheless pose an appreciable long-term hazard:

- Prompt radiation from the nuclear explosions could inflict sublethal doses on some survivors, especially if the weapons are small ones. Most of the radiation absorbed by survivors of the Hiroshima and Nagasaki attack was direct radiation. A substantial number of U.S. weapons have yields in the tens of kilotons, and might inflict radiation on people far enough away from the explosion to survive the blast effects. Few Soviet weapons are of such low yields and high-yield weapons are expected to kill those within radiation range by blast. A terrorist weapon would almost certainly inflict direct radiation on survivors. There is a particular area of uncertainty regarding the effects on humans of low levels of neutron radiation.
- Local fallout will inflict small doses of radiation on people who are on the fringe of "fallout zones, " or on people who are in fallout shelters in zones of heavier fallout. It is important to realize that even the best fallout shelters attenuate fallout rather than block it completely, and the whole theory of fallout shelters is to see to it that people who would, if unsheltered, receive a lethal dose would instead receive a sublethal dose. However, this sublethal dose will produce harmful long-term effects for some percentage of those exposed.
- After a period of time, local fallout radiation levels decay to the point where the area would be considered "safe," and survivors in fallout shelters would emerge. Nevertheless, low levels of radiation would persist for some time— indeed, low levels of radiation have persisted for years at some sites of nuclear weapons tests. The question of safety here is a relative one. By the standards of peacetime, many such areas would be considered unsafe, because living in them would expose a population to a significant risk of long-term hazards— cancer, genetic damage, etc. However, in the aftermath of a nucle ar attack, there may be few habitable areas that do not have a measurable (though low) level of additional radiation, and the survivors would simply have to accept the hazards.
- Some fallout is deposited in the troposphere, and then is brought down to Earth (largely by rain) over a period of weeks. Such fallout reaches areas quite far from the blast. While the doses inflicted would be relatively small, they would add to the risk.
- Some fallout is deposited in the stratosphere. It returns to Earth over a period **of** years (through the effects of gravity), and consequently only very long-lived radioactive isotopes pose a significant hazard. If the attacks are confined to the territory

of the United States and the Soviet Union (and, for that matter, to Europe and China as well), then stratospheric fallout will be confined mostly to the Northern Hemisphere, and the region between 300 and 600 north latitude will receive the bulk of it.

In quantifying the radiation dose received by individuals, radiation from external and internal (ingested) sources must be distinguished. External radiation passes through the skin. Ingested radioactivity derives its effects from particular radioactive isotopes becoming concentrated in specific organs. For example, radioactive iodine (l-1 31), which may enter the body through breathing, eating, and drinking, is concentrated in the thyroid, and radioactive strontium (Sr 89 and Sr 90) is concentrated in bone.

An OTA contractor performed a series of calculations to estimate the magnitude of the long-term health hazards that would be created by the long-term, low-level radiation that each of the OTA cases might produce. The basic method was to calculate the total amount of radiation that all the survivors of each hypothetical nuclear attack might absorb during the 40 years following the attack, and then calculate the numbers of adverse health effects that this much radiation could be expected to produce. (Tables 12 and 13 present the risk factors used for these calculations.) The difficulties in such a procedure are formidable, and precise results are manifestly impossible to obtain.

The major uncertainties, which result in a wide range of answers, are the following:

- All of the uncertainties discussed in previous chapters about the size and nature of the attack, and the distribution of the population.
- How much of the population benefits from what degree of fallout sheltering? It has been noted that there is no necessary relation between civil defense plans and actual shelter received.
- How many people die in the immediate aftermath of the attack?

Table 12.—Assumed Effects of Radiation Exposures

Effect	Number per million person-rems[a]
***Somatic effects*†**	
Cancer deaths (DEF = 1)*	194.3[b c]
Cancer deaths (DEF = 0.2)	38.9[d]
Thyroid cancers	131.4[e]
Thyroid nodules	197.4[e]
***Genetic effects*†**	
Abortions due to chromosomal damage	21-210[f]
Other genetic effects	66-660[f]

†These effects are in addition to those expected from natural or background causes.
*DEF = Dose effectiveness factor.
[a] This assumes that total exposure is governing—that is, that 1 rem each to a million people produce the same effects as 10 rems each to 100,000 people.
[b] This figure is modified from values presented in table VI. 9-4 of the Nuclear Regulatory Commission Reactor Safety Study (WASH 1400). The rationale for the modification was that although the latent period for cancer induction used by WASH 1400 was deemed appropriate, there is insufficient evidence that the plateau periods are limited to 30 years. Using the latent periods in WASH 1400 and the remaining lifespan as the plateau period along with the population age distribution, the cancer risk coefficients in the WASH 1400 study were converted to those in this table.
[c] See table 12 for the sources of these cancer deaths.
[d] Arrived at by multiplying the DEF = 1 figure by 0.2.
[e] Taken from table VI. 9-8 of the WASH 1400 report.
[f] These figures were derived from tables VI. 9-11 and VI. 9-12 of the WASH 1400 report. The range is based on a range of possible doubling dose from 20 to 200 rems, as suggested by the BEIR report (Washington, D.C.: National Academy of Sciences, 1972), p. 53.

Table 13.—Assumed Sources of Cancer Deaths[a]

Cancer type	Cancer deaths per million organ-rems
Leukemia	45.4
Lung	35.5
Digestive tract	27.1
Bone	11
Others	75.3

[a] See footnotes a and b to table 12.

- Does radiation that is part of a low exposure or a very slow exposure do as much damage per rem absorbed as radiation received as part of a high and rapid exposure? One theory holds that, given time, the body can repair the damage done by radiation, and that hence the same dose spread over years does less damage than it would if received within a few days. Another theory is that radiation damages the body in ways that are essentially irreparable. The contractor calculated the effects both ways (DEF = 1 and DEF = 0.2), which accounts for some of the range in the answers.
- Is there a threshold dose below which radiation exposure does no harm at all? If there is, then the methodology used produces somewhat exaggerated results,

since it attributes damage to radiation absorbed by people whose total dose is below the threshold.

- How to deal with the distribution of ages of the population at the time of the attack, since susceptibility to cancer, etc., from causes other than radiation varies with age.

- How great are the genetic effects from a given level of radiation? Extensive experimental results permit an approximate calculation of the number of mutations that would be produced, although one source notes that the doubling dose for genetic disorders might be anywhere from 20 to 200 reins. However, it is far more difficult to predict exactly how these mutations would manifest themselves in future generations.

The results of these calculations are summarized in table 14. [The full report of the contractor is available separately.) The ranges result from the uncertainties noted above, and it is expected that the "actual" results if a war took place would be some distance from either extreme. It is observed that:

- Cancer deaths in the m i I I ions could be expected during the 40 years following a large nuclear attack, even if that attack avoided targets in population centers. These millions of deaths would, however, be far less than the immediate deaths caused by a large attack on a full range of targets.
- A large nuclear war could cause deaths in the low millions outside the combatant countries, although this would represent only a modest increase in the peacetime cancer death rate.
- These results might not apply if an attacker set out deliberately to create very high radiation levels.

Just as this study was going to press, the results of the new report of the Committee on the Biological Effects of Ionizing Radiations ("BEIR II") of the National Academy of Sciences (NAS) became available. (The full report, entitled "The Effects on Populations of Exposure to Low Levels of Ionizing Radiations," will be published by NAS during the second half of 1979.) In general, the new report suggests a slightly narrower range of uncertainty than the OTA calculations, but generally confirms their assumptions. OTA used assumptions of cancer deaths per million person-reins which appear to be about 10 percent higher at the high end of the range and about 40 percent lower at the low end of the range than the findings of the new BEIR report. OTA calculated genetic effects on the basis of a doubling dose of 20 to 200 reins, compared with a range of 50 to 250 reins suggested by the new BE I R report, which may mean that the OTA estimates are too high at the high end of the range. The new BEIR report also notes that the incidence of radiation-induced cancer would be higher for women than for men.

EFFECTS ON THE OZONE LAYER

Large nuclear explosions would, among other things, inject a variety of particles into the upper atmosphere. In recent years, considerable attention has focused on the possibility that the injection of a substantial quantity of nitrogen oxide (NO_x) into the stratosphere by a large number of high-yield nuclear weapons might cause a depletion or thinning of the ozone layer. Such a depletion might produce changes in the Earth's climate, and would allow more ultraviolet radiation from the Sun through the atmosphere to the surface of the Earth, where it could produce dangerous burns and a variety of potentially dangerous ecological effects.

As of 1975, a report by the National Academy of Sciences (discussed more fully below)

Table 14.–Long-Term Radiation Effects From Nuclear Attacks[a]

A. Air Bursts

Estimated worldwide[b] effects from 1-Mt air burst over a city (OTA Case 1):

Somatic effects	
Cancer deaths	200 - 2,000
Thyroid cancers	about 700
Thyroid nodules	about 1,000
Genetic effects	
Abortions due to chromosomal damage	100 - 1,000
Other genetic effects	350 - 3,500

Estimated worldwide[b] effects from an attack using 78 air bursts of 1 Mt each (OTA Case 2 attack on the United States) are 78 times as great, that is:

Somatic effects	
Cancer deaths	16,000 - 160,000
Thyroid cancers	about 55,000
Thyroid nodules	about 78,000
Genetic effects	
Abortions due to chromosomal damage	8,000 - 80,000
Other genetic effects	27,000 - 270,000

Estimated total[c] effects from an attack using 72 air bursts of 40 kt each (OTA Case 2 attack on U.S.S.R.):

Somatic effects	
Cancer deaths	6,000 - 60,000
Thyroid cancers	about 50,000
Thyroid nodules	about 80,000
Genetic effects	
Abortions due to chromosomal damage	2,500 - 25,000
Other genetic effects	5,000 - 50,000

B. Limited Surface Bursts

Estimated total[c] effects of an attack on U.S. oil refineries using surface bursts, with fallout sheltering treated parametrically

Somatic effects	PF* = 5	PF* = 10	PF* =40
Cancer deaths	2,000.000-5.500,000	1,000,000-3,000>000	300,000-1 ,000! 000
Thyroid cancers	about 2,000,000	about 1,000,000	about 300,000
Thryold nodules	about 2,500,000	about 1,500,000	about 500,000
Genetic effects			
Abortlons due to chromosomal damage	250,000-2,500,000	150,000-1,500,000	50,000-500,000
Other genetic effects	900,000-9,000,000	500,000-5,000,000	150,000-1,500,000

Estimated effects outside he United States from this attack

Somatic effects	
Cancer deaths	8,000-80,000
Thyroid cancers	about 30,000
Thyroid nodules	about 50,000
Genetic effects	
Abortlons due to chromosomal damage	4,000- 40,000
Other genetic ffects	13,000-130,000

C. Counterforce Attacks (Mixed air and surface bursts—Case 3)

Estimated total[c] effects of an attack on U.S. ICBM silos, using one air burst and one surface burst (each 1 Mt) against 1,054 silos. A case in which bomber and submarine bases are also attacked with air bursts gives similar results. Fallout sheltering is treated parametrically:

Somatic effects	PF = 5	PF = 10	PF = 40
Cancer deaths	1,000,000-6,000,000	700,000-5,000,000	500,000-4,500,000
Thyroid cancers	about 2,000,000	about 2,000,000	about 1,500,000
Thyroid nodules	about 3,000,000	about 3,000,000	about 2,500,000
Genetic effects			
Abortions due to chromosomal damage	300,000-3,000,000	250,000-2,500,000	200,000-2,000,000
Other genetic effects	900,000-9,000,000	750,000-7,500,000	650,000-6,500,000

Estimated effects outside the United States from this attack:

Somatic effects	
Cancer deaths	400,000 - 3,800,000
Thyroid cancers	about 1,400,000
Thyroid nodules	about 2,000,000
Genetic effects	
Abortions due to chromosomal damage	170,000 - 1,700,000
Other genetic effects	600,000 - 6,000,000

Estimated total[c] effects of an attack on Soviet ICBM silos, using one air burst and one surface burst (each 100 kt) against 1,477 silos. The overwhelming bulk of deaths are from "worldwide" (between 30° and 60° north latitude) fallout, and hence fallout sheltering in the Soviet Union makes little difference:

Somatic effects	
Cancer deaths	300,000 - 3,300,000
Thyroid cancers	about 2,500,000
Thyroid nodules	about 3,600,000
Genetic effects	
Abortions due to chromosomal damage	120,000 - 2,500,000
Other genetic effects	400,000 - 4,000,000

D. Comprehensive Attacks (Case 4)

Estimated effects inside the United States of an attack on military and economic targets in the United States consisting of 3,325 weapons with a total yield of 6,500 Mt. A mixture of air bursts and surface bursts was assumed, and the ranges include variations in fallout protection available:

Somatic effects	
Cancer deaths	1,000,000 - 5,500,000
Thyroid cancers	1,000,000 - 2,000,000
Thyroid nodules	1,500,000 - 2,500,000
Genetic effects	
Abortions due to chromosomal damage	150,000 - 6,000,000
Other genetic effects	400,000 - 9,000,000

Estimated effects outside the United States:

Somatic effects	
Cancer deaths	900,000 - 9,000,000
Thyroid cancers	about 3,200,000
Thyroid nodules	about 4,500,000
Genetic effects	
Abortions due to chromosomal damage	500,000 - 5,000,000
Other genetic effects	1,500,000 - 15,000,000

Estimated total[c] effects of an attack on military and economic targets in the Soviet Union consisting of 5,660 weapons with a total yield of 1,300 Mt. A mixture of air bursts and surface bursts was assumed, and the ranges include variations fallout protection

Somatic effects	
Cancer deaths	1,200,000-9,300,000
Thyroid cancers	about 5,500,000
Thyroid nodules	7,700,000-8,400,000
Genetic effects	
Abortins due to chromosomal damage	320,000-8,000,000
Other genetic effects	1,000,000-12,500,000

*PF = Protection factor. [a]Assumptions and sources are those used for tables 12 and 13. [b]Most worldwide fallout would be in the Northern Hemisphere, and it would be concentrated between 30° and 60° N Latitude. [c]Includes worldwide totals (note b above), but effects are greater in the target country than elsewhere called attention to this danger as a serious one, estimating that a 30- to 70-percent reduction in the ozone column was a possibility.

Since that time, however, there have been two changes which bear on the question of the degree of risk of ozone depletion:

1. Further research into the chemistry of the upper atmosphere has modified the model calculations used in 1975. The results of past nuclear tests do not, however, provide data adequate for the complete validation of any chemistry model. There are also indications that the chemistry concerned is much more complex than was formerly believed. The state of knowledge in early 1979 is roughly this: injections of NO. could deplete the ozone layer if they occur at very high altitudes (80,000 ft [24 km] and upwards), which would result from very high-yield explosions (i.e., substantially more than 1 Mt) in large numbers (1 ,000 or more), or possibly from high-altitude explosions. Otherwise, ozone depletion is not believed to be likely. However, further changes in the theory of what would happen are likely in the future.
2. The development of MIRVs has reduced the number-of very high-yield warheads in the arsenals of the superpowers, as they are replaced by multiple weapons of lower yield.

These changes cast doubt on the likelihood of serious ozone depletion as a consequence of nuclear war. However, they by no means demonstrate that ozone depletion is impossible, and even slight depletion could cause an increase in the incidence of skin cancer.

This is an area where research continues, and further changes should not be surprising.

INCALCULABLE EFFECTS

In 1975, the National Academy of Sciences published a report, Long-Term Worldwide *Effects of Mu/tip/e Nuclear-Weapons Detonations,* which addressed the question of whether a large-scale nuclear war would be likely to produce significant, irreversible effects on the world environment.

This document may be summarized as follows:

- It is possible that a large nuclear war would produce irreversible adverse effects on the environment and the ecological system.
- In particular, it would not require very large changes to greatly diminish the production of food. The report notes that it would be difficult to adapt to such changes in view of the likelihood that much of the world's expertise in agricultural technology might perish in the war.
- The physical and biological processes involved are not understood well enough to say just how such irreversible damage, if it occurred, would take place.

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. Therefore, it is not possible to estimate the probability or the probable magnitude of such damage.

With the exception of the discussion of possible damage to the ozone layer, where there has been some advance in knowledge since 1975, these conclusions still hold in 1979.

Moreover, there are at least two other respects in which there are hazards whose magnitude cannot be calculated. It is certain that the radiation derived from a nuclear war would cause mutations in surviving plants and animals; it is possible that some of these mutations might change the ecosystem in unpredictable ways, but this seems unlikely. Furthermore, the possibility cannot be excluded of major changes in human behavior as a result of the unprecedented trauma. Science fiction writers have speculated, for example, that in the aftermath of a nuclear war, the survivors would place the blame on "science" or on "scientists," and through a combination of lynching and book-burning eliminate scientific knowledge altogether. There are cases in history (or rather archeology) of high civilizations that simply stopped functioning (though people survived biologically) after some shattering experience.

FINDINGS

The calculations for long-term radiation hazards, with all their uncertainties, permit an order-of-magnitude conclusion:

- There would be a substantial number of deaths and illness due to radiation among those who were lucky enough to escape a lethal dose during the first weeks after the attack.
- The number of deaths would be very large by peacetime standards, and the hazards much greater than what is considered tolerable today.
- The number of deaths would be rather small compared to the number of deaths resulting from the immediate effects of the attack — millions compared to tens or hundreds of millions.

In contrast, the incalculable effects of damage to the Earth's ecological system might be on the same order of magnitude as the immediate effects, but it is not known how to calculate or even estimate their likelihood.