**Treatment of a Severe Burn**

20-year-old man
85% of body surface: full-thickness burns (from a gasoline explosion)
33 hospital days (died on 33rd day)
501 transfusions:

| | |
|---|---|
| fresh frozen plasma | 281 units |
| fresh frozen red blood cells | 147 units |
| platelets | 37 units |
| albumin | 36 units |

6 operations

| | |
|---|---|
| medical personnel hours | 4900 |
| approximate daily cost | $3500 |

From John F. Burke, M.D., Chief of Trauma Services, Massachusetts General Hospital, July 1980.

Even though there are 30-bed burn units, such as the Shriners or those at large general hospitals, they can handle only two or three fresh severe burns at once. If a large group of such burns occurred in a major accident, they would have to be distributed for effective treatment.

Major burn disasters of recent years—the Coconut Grove and Hartford Circus fires—and various plane crashes have resulted in very few survivors of major burns. Initially following a nuclear attack, there would be thousands, or even tens of thousands, severely burned immediate survivors. Even the most conservative calculation of thermal injuries resulting from an isolated one-megaton or "minimal" nuclear explosion, with hypothetical preservation of all U.S. medical facilities and the availability of immediate and perfect triage and transportation, shows that what we consider to be one of the most lavish and well-developed medical facilities in the world would be completely overwhelmed. It is impossible to imagine the chaos that would result from a larger explosion in which the hospitals themselves were partially destroyed and where there was no possibility of significant triage or inter-center transportation. The medical facilities of the nation would choke totally on even a fraction of the burn casualties alone.



# 16

# Survivors of Nuclear War: Infection and the Spread of Disease

Herbert L. Abrams, M.D.

The devastation and chaos that would follow an all-out nuclear war and the potential for regression to a social structure unknown to twentieth century industrialized society have been well emphasized. But the nature of the medical problems that would confront survivors has not been widely conveyed. The effects of burn, blast, and radiation have dominated discussions of the post-attack period. In the intermediate term, however, infection and the spread of communicable disease would represent the most important threat to survivors.

In depicting a massive nuclear exchange, we will assume that the United States has undergone a 6500-megaton attack, the so-called CRP-2B model used by the U.S. Federal Emergency Management Agency in civil defense planning. In terms of yield, it

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*Table 1. Casualties from a 6500-megaton attack on the United States.*

| Cause | Fatalities (millions) | Injured or Affected (millions) |
|---|---|---|
| Trauma, flash burns | 86 | 34 |
| Trapped by debris | 5 | 2 |
| Secondary fires | 3 | 1 |
| Lack of water | 1 | 4 |
| Inadequate shelter ventilation | 1 | 5 |
| Fallout radiation | 38 | 23 |
| Net casualties | 134 | 33 |

*Source:* U.S. Federal Emergency Management Agency, 1979, p. 3. This publication gives the pre-attack population as 237 million. Since our present population is about 225 million, the figures were all adjusted accordingly, so as not to differ from other casualty estimates used (by FEMA) that assume about 225 million. Those "affected" by fires, water, and lack of ventilation are said to be "forced out [of shelter] by. . . ." This implies they might have been killed by radiation as much as by actual burns, dehydration, or suffocation.

represents 524,000 Hiroshima bombs. The targets of attack, in order of priority, would include:

- military installations
- military-supporting industrial, transport, and logistic facilities
- other basic industries and facilities that contribute to the maintenance of the economy
- population concentrations of 50,000 or greater

Some 4000 megatons would be detonated on urban areas and population centers. Moments after the attack, 86 million people—nearly 40 percent of the population—would be dead (Table 1). An additional 34 million—27 percent of the survivors—would be severely injured. Forty-eight million additional fatalities are anticipated during the shelter period, for a total of 134 million deaths. Many of the millions of surviving injured would experience moderate to high radiation doses and would have residual blast and burn injuries.

Table 2 lists the medical problems resulting from this 6500-megaton attack. The periods under consideration are as follows:



*Table 2. Medical problems during the attack and in the post-attack period.*

| Medical Problem (in approximate order of time in which inflicted) | Shelter Period | | | | Long-Term Effects | |
|---|---|---|---|---|---|---|
| | First Hour | First Day | First 0-4 Weeks | Survival Period | Recovery Period | Future Generations |
| Flash burns | + | | | | | |
| Trauma | + | | | | | |
| Flame burns and smoke inhalation | + | + | | | | |
| Acute radiation | + | | | | | |
| Fallout radiation | + | + | + | + | | |
| Suffocation and heat prostration | | + | + | | | |
| General lack of medical care | | + | + | + | | |
| Dehydration | | | + | | | |
| Communicable diseases | | | + | + | | |
| Exposure and hardship | | | + | + | | |
| Malnutrition | | | + | + | | |
| Cancer | | | | | + | |
| Genetic effects | | | | | | + |

*Immediate Effects.* During the barrage period, the explosions almost instantaneously would inflict millions of lethal and nonlethal blast, thermal, and immediate radiation injuries on those caught in and around the blast areas.

*Shelter Period.* From the time of the attack to days or weeks later, those surviving the initial explosion would attempt to sustain themselves in fallout shelters, amid intense radiation, fires, and deprivation.

*Post-Shelter Survival.* Fallout would reach a level "acceptable" for emergencies after variable time periods. The problems of attaining food, finding shelter, and recovering from acute injury would have to be confronted. The injured would need to be nursed, the dead buried, debris cleared, the harvest reaped, and the next har-

> **I refuse to accept the cynical notion that nation after nation must spiral down a militaristic stairway into the Hell of nuclear destruction.**
>
> Martin Luther King, Jr., 1964

vest sown. In a hazardous environment, survival would be the only meaningful goal.

*Long-Term Effects.* Survival would be accomplished and some kind of recovery initiated. Some societal structure would emerge, food supplies secured, shelter obtained, and communities established. A primitive social organism would be strained by intense competition for food supplies. During the early years, the first cases of radiation-induced leukemia would appear; later the solid cancers would develop in the lungs, thyroid, breast, and colon.

The problems of infection and communicable disease would be severe during the shelter period and more particularly during post-shelter survival. They require careful consideration, not only because of human cost, but also because of their impact on the recovery process. What, then, is the nature of the threat: why is the likelihood of infection so much greater in the post-attack world?

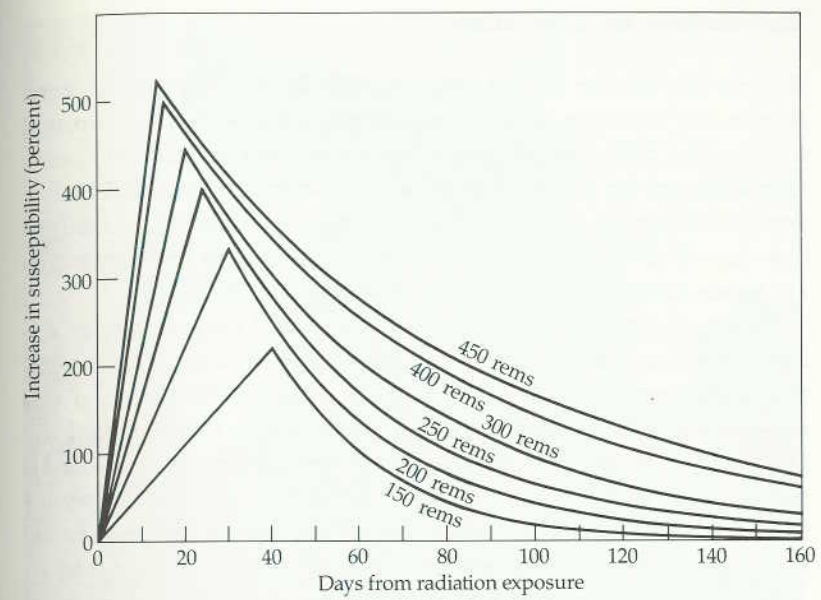
## Increased Risk and Severity of Infection

Most survivors would experience increased susceptibility to infection because of both the pervasive direct effects of nuclear weapons and the subsequent pressures and hardships confronted. Several factors would be of special importance.

### Radiation

Radiation affects the immune system in a number of different ways, not least of which is its capacity to injure the bone marrow and the lymph nodes. Hematologic changes may occur with doses as low as 50 rems: decreased antibody response, decreased effectiveness of cellular defense mechanisms, decreased effectiveness of immunizing agents, and increased susceptibility to some toxins. Consequently, vaccination would be less effective.






*Effect of radiation exposure on disease susceptibility over time. (From Voors and Harris, 1970.)*

Radiation also has a major effect on the lining or mucous membrane of the intestine. The ulcerated lining provides a portal of entry for intestinal bacteria into the bloodstream, with bloodstream infection as a certain sequel. These organisms are frequently difficult to control with antibiotics.

Twenty-three million survivors of a large-scale nuclear war would suffer from radiation sickness, evidence that they received a mean dose of 200 rems or more. But the number of cases with doses between 100 and 200 rems would probably equal that number, so that 50 percent of the surviving population might have lowered resistance to disease from radiation exposure alone, extending over a period of many months (see the figure above).

### Trauma and Burn Casualties

Among the millions suffering from trauma and/or burns, over a third also would suffer from radiation sickness. Aside from the risk of infection related to the open wounds, weakness and incapacitation could be expected to increase general vulnerability. There is also a known synergy between burns and radiation that profoundly increases the mortality rate.

## Malnutrition and Starvation

During the shelter period, the availability of food would vary. Adults can maintain health for several weeks with only minimal food intake, but in some locales, fallout might prevent emergence from shelters for longer periods of time so that nutritional health would deteriorate. Infants and young children, in particular, might experience severe malnutrition due to insufficient or inappropriate foods during an extended shelter stay.

During the post-shelter phase, three crucial periods can be defined: shelter emergence until the first harvest, first harvest until the next harvest, and all subsequent seasons. The first two periods depend a great deal on the time of year the attack occurs, and the third depends on post-attack recovery and environmental conditions. Upon shelter emergence, most of the food stores would have been destroyed in urban areas; remaining supplies most likely would be consumed during or soon after the shelter period.

The essential supply of available food would be the grain stored in small towns and rural areas. The lives of millions of survivors would depend upon this supply until the next harvest was avail-

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**beta-hemolytic *Streptococcus*** a type of bacterium that most frequently causes acute infections, such as tonsillitis, but can result in serious complications involving the heart (acute rheumatic fever) and kidneys (acute glomerulonephritis).

**bubonic plague** an acute infectious disease, transmitted to humans by infected rats and other rodents, characterized by lymph node enlargement and high mortality.

**endemic disease** infectious disease prevalent in a particular locality.

**pneumonic plague** a highly infectious and almost always fatal form of plague involving the lungs and transmitted from human to human without a rat vector.

**rem** 450 rems of total body irradiation is considered the dose that will kill approximately 50 percent of the healthy adults exposed.

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*World War II: the face of hunger, during the siege of Leningrad. A starving man holding his daily ration of bread. The bread was often made from ingredients such as moldy flour, cellulose, and cotton seed. (Sovfoto.)*

able. The amount of stored grain varies considerably during the course of the year. Supply for the surviving population might vary from 200 to 500 days, with great dependence on the next harvest.

But food piled high in silos in remote regions would do little good for a hungry populace. Grain would have to be obtained, transported, and distributed to the survivors where they were located. Grain transportation would be the most important survival activity in the immediate post-shelter period. This problem would be made much more difficult by the negative correlation that exists in the United States between population and grain density (see the figures on the facing page).

Furthermore, assuming that trucks and highways would be usable, an essential commodity for the transportation of grain is fuel. It is estimated that as much as 99 percent of U.S. refining capacity could be destroyed during the 6500-megaton attack.

### Exposure and Hardship

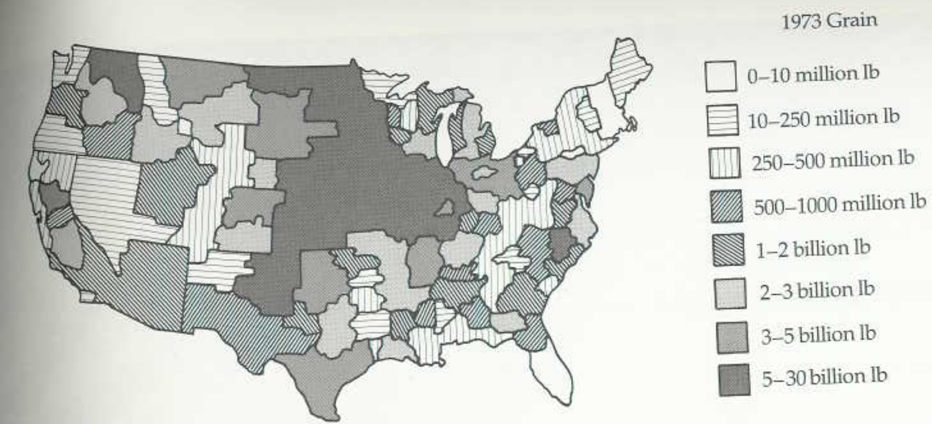
Widespread destruction of urban housing would occur, with major damage to rural housing as well. Heating fuel might be unavailable. General hardship, with exposure, poor nutrition, and exhaustion increased by enormous physical demands, would follow and would promote great vulnerability to infection.

### Lowered Natural Resistance to Disease

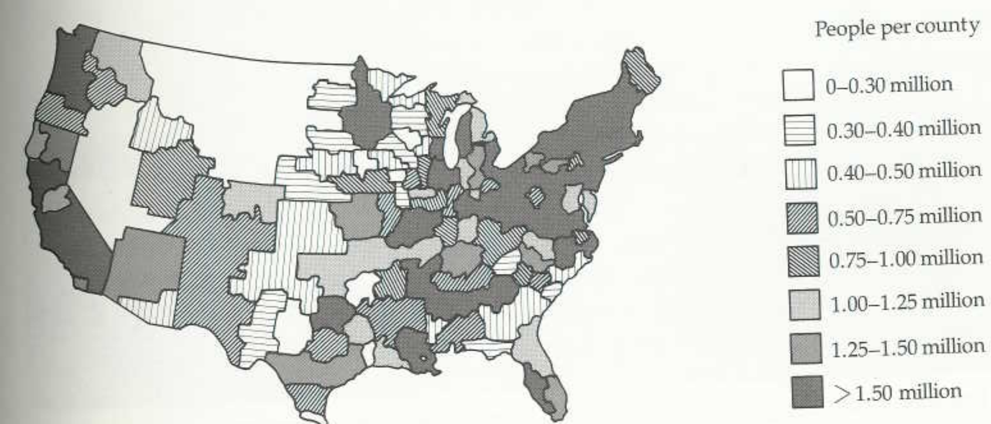
Surviving Americans would for the first time experience the underdeveloped world as their natural habitat. Unlike the population of impoverished lands, however, Americans do not have the high natural immunity to a host of dangerous diseases that allows many in the Third World to survive. The omnipresence of antibiotics has altered the normal production of antibodies to infectious agents among the developed nations. Because of the destruction of the pharmaceutical industry, as well as post-attack disorganization and chaos, antibiotics would be in short supply for countries that have depended on them.

Successful campaigns to eliminate lethal epidemics, such as cholera and typhoid fever, have been accompanied by a failure to develop resistance to these diseases. Reintroduction of such "ex-






*U.S. grain density. (From Haaland, Chester, and Wigner, 1976, p. 149.)*




*U.S. relocated-population density. (From Haaland, Chester, and Wigner, 1976, p. 146.)*

otic" diseases might find the population incapable of handling them, as were American Indians when exposed to the diseases of Europeans. Measles, whooping cough, and diphtheria might run rampant in un-immunized infants, and beta-hemolytic streptococcal infections would be widespread.

## Factors Increasing the Spread of Disease

### Shelter Conditions

Large public shelters probably would operate under severe limitations, with thousands packed into inadequate areas. Under these circumstances, hepatitis and respiratory and gastrointestinal infections might spread rapidly. Most shelters would lack adequate ventilation. When ventilation systems were present, the blowers and fans could easily be rendered inoperable by an overpressure of 1 psi and the systems blocked by electric power failure. Heat and humidity in the shelter would then increase, and the absence of a continuous flow of fresh air would encourage the spread of infective microorganisms.

The length of time that fallout radiation would enforce basement and underground occupancy would be an important determinant of disease spread. This period might be several months. Those in highly radioactive cities would have much longer stays and might have significant exposures even in shelters. Even after it became permissible to work outside, it might still be necessary to eat, sleep, and rest in fallout shelters.

### Sanitation

The barriers to communicable disease spread accomplished today by a sanitary water supply, properly prepared and refrigerated food, sewage treatment, and waste disposal would be seriously compromised in the post-attack environment.

Impure water, contaminated food, and general unsanitary conditions would spread a host of intestinal diseases not yet experienced by most Americans. These include infectious hepatitis, *E. coli*, *Salmonella*, *Shigella*, amebic dysentery, and possibly typhoid and paratyphoid.



*An old woman and flies. Immediately after the bombing, there was an increase in the number of flies, and maggots got into the wounds of many victims. Hiroshima, September 1945. (U.S. Navy, Hiroshima; Hiroshima–Nagasaki Publishing Committee.)*

### Insects

Insects are generally more resistant to radiation than humans. This resistance and the existence of corpses, waste, lack of sewage treatment, depletion of birds, and destruction of insecticide stocks and production would engender a huge increase in insect growth. The absence of control of insect growth, combined with failure to provide adequate sanitation, might sharply limit the capacity to control such diseases as typhus and dengue fever.

### Corpses

The health problem created by millions of corpses post-attack would represent a serious disease threat. In many areas radiation levels would be so high that corpses would remain untouched for weeks on end. With transportation destroyed, weakened survivors, and a multiplicity of post-shelter reconstruction tasks to be performed, corpse disposal would be enormously complicated. To bury the dead, after a 6500-megaton attack, an area 5.7 times as large as the city of Seattle would be required for the cemetery.

## Factors Limiting the Response to Infection

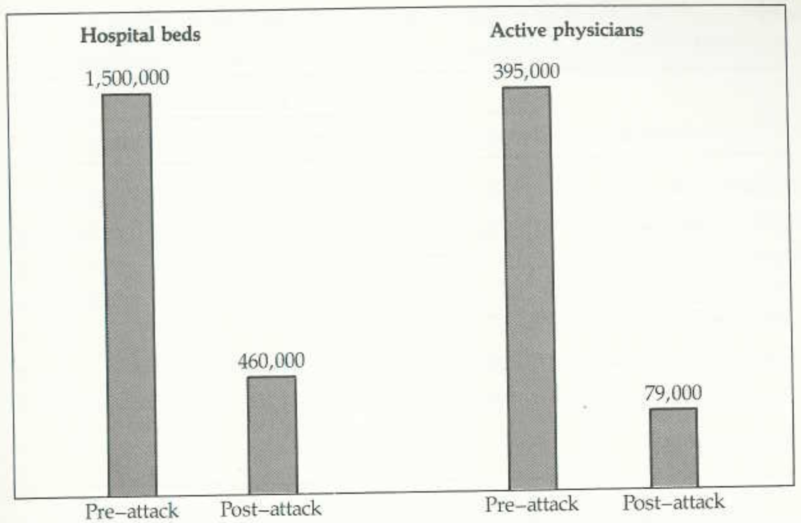
### Government Organization

The United States has developed an extraordinary ability to take effective countermeasures against communicable diseases. Should an outbreak occur, a public health network is informed, the rest of the country alerted, and appropriate steps taken. In 1947 a man infected with smallpox mingled with New York City crowds for several days. More than 6,350,000 persons were immediately vaccinated; as a result, only 12 additional cases appeared. More recently, the unfortunate swine flu episode illustrated how the hint of an epidemic could bring enormous medical resources to bear upon the threat.

Coherent efforts to control and limit the spread of disease require surviving government, organized geographic units, communication networks, and a favorable enough survival situation so that physicians and health officials can perform their tasks.

All of these conditions are speculative in the post-attack world. Most radio contact would be eliminated by nuclear weapons effects. Treating the wounded would require the full attention of available medical resources. For a sustained period, surviving officials might have to remain in shelters, with the acquisition and supplying of food and water their primary concern. The huge number of injured, the tenuous food situation, massive industrial destruction, enormous debris removal and body disposal tasks, and disparity between "food-rich" and "food-poor" regions would undermine interregional cooperation seriously.






*U.S. medical resources after a nuclear war. (Federal Emergency Management Agency, 1980, p. 63.)*

### Disease Detection, Diagnosis, and Treatment

Health countermeasures against potential epidemics depend upon the availability of resources and the involvement of physicians. Many hospital beds would be destroyed, and casualties among physicians and other health personnel would approximate 80 percent (see the figure above). This percentage is higher than the casualty percentage for the population as a whole (73 percent) because physicians are disproportionately represented in large cities.

If we assume that the average shelter contains 100 people, and that no more than one physician would be in any shelter, then, using U.S. government estimates for surviving, uninjured physicians, only one in twelve shelters would have a functioning physician. If a serious epidemic occurs, it would affect physicians as well. More physicians would become incapacitated as the number of sick increased, further raising the injured to physician ratio.

Laboratories are essential for dealing with communicable disease, but they would be highly vulnerable to the effects of an attack.

*Table 3. Principal communicable disease countermeasures by mode of transmission.*

| Countermeasure | Mode of Transmission: Intestinal | Human-to-Human | Vector-borne |
|---|---|---|---|
| Antibiotics | + | + | + |
| Excreta disposal | + | – | – |
| Food hygiene | + | – | – |
| Immunization | +* | + | – |
| Potable water | + | – | – |
| Public information | + | + | + |
| Vector control | + | – | + |

*Typhoid fever only.
*Source:* Johnson et al., 1978.

Thus the prompt detection and diagnosis of communicable diseases essential to the identification of medical resource needs would be impeded severely during a crucial period.

### Inadequacy of Countermeasures

Many of the countermeasures required for intestinal and vector-borne diseases would be unavailable in the disorganization of the post-attack period. Their control involves assuring supplies of pure water and uncontaminated food, disposal of sewage and waste, and removal of breeding areas for insects and rodents (Table 3). Both antibiotics and immunization would play an essential role in stemming epidemics. But how effective would they be?

*Antibiotics.* Antibiotics are ineffective in combating viral disease and cannot limit the spread of such infections as smallpox, viral gastroenteritis, and influenza. Several dangerous bacterial diseases such as diphtheria and tetanus respond poorly to antibiotics. Furthermore, the demand for antibiotics would be large. If laboratory tests were not available, they would be prescribed for all undiagnosed ailments. Most stores of antibiotics in urban centers would be destroyed, and those still intact might be inaccessible for days or weeks because of intense fallout radiation. The pharmaceutical industry would be virtually eliminated in a massive attack.



*Immunization.* For several hazardous diseases, such as tetanus, poliomyelitis, measles, whooping cough, and typhus, immunization is the only effective direct means of control. In post-attack conditions, however, the effectiveness of vaccination programs would be diminished by the impact of radiation on the immune system. Millions who had substantial radiation doses and therefore needed immunization most of all would benefit least.

## Potential Pathogens in the Post-Attack World

Studies performed in the late 1960's identified 23 diseases that might be significant in the post-attack environment, 18 of which are listed in Table 4. Many of these are encountered in endemic form throughout the country. Among them, potential epidemic sources may be divided into two categories. The first includes the classic epidemic diseases, fortunately of low incidence; the second, diseases of heightened incidence but low mortality (Table 5). Respiratory diseases, including viral pneumonias, influenza, pneumococcal and streptococcal infections, and tuberculosis infections would affect particularly those living in crowded fallout shelters, with an augmented impact on the young and the old. The diarrheal diseases caused by the bacteria *Salmonella*, *Shigella*, and *Campylobacter* and viral gastroenteritis would be widely prevalent. Although their mortality rate is usually low, in the presence of radiation injury to the gastrointestinal tract it would be increased substantially. Furthermore, these diseases, as well as infectious hepatitis, spread rapidly in the absence of adequate sewage disposal, pasteurized milk, or appropriate sanitary precautions. The group of diseases endemic to rural areas, and thus a danger to evacuated populations, includes rabies, plague, and tetanus. Other diseases such as cholera or influenza might spread rapidly in devastated areas.

A more detailed view of two among many diseases that are generally considered well controlled in Western society will indi-

*Table 4. Infectious diseases in the post-attack period.*

| Communicable Disease | Reported Cases in the United States in 1979 |
|---|---|
| Amebiasis | 4107 |
| Diphtheria | 59 |
| Encephalitis, arthropod-borne, viral | 1266 |
| Food poisoning (botulism) | 45 |
| Food poisoning (salmonellosis) | 33,138 |
| Hepatitis, A | 30,407 |
| Influenza | 0.3* |
| Measles | 13,598 |
| Meningococcal meningitis | 2724 |
| Plague | 13 |
| Pneumonia | 19.7* |
| Rabies | 4 |
| Shigellosis | 20,135 |
| Smallpox | 0 |
| Tuberculosis | 27,669 |
| Typhoid fever | 528 |
| Typhus | 69 |
| Whooping cough | 1623 |

*Death rate per 100,000 in 1979.
*Source:* Center for Disease Control, 1980, p. 3.

cate the roots of the concern for the role for communicable disease in the transformed post-nuclear-war world.

## Tuberculosis

Tuberculosis, the Great White Plague of the nineteenth century, was a lethal infection for large segments of the population. Death rates as high as 550 per 100,000 were reported in New York City. If the annual U.S. death rate of 184.7 per 100,000 from tuberculo-



*Table 5. Potential epidemic diseases.*

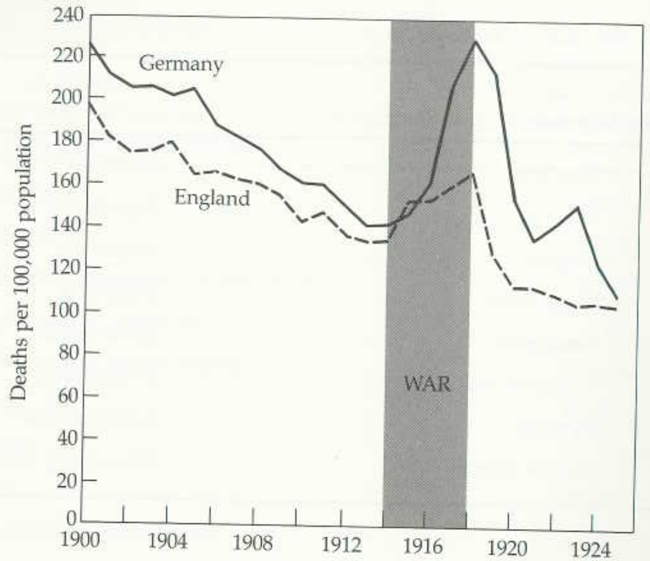
| Group 1: Epidemic Diseases of Low Incidence | Group 2: Serious Existing Diseases |
|---|---|
| Cholera | Diarrhea |
| Malaria | Diphtheria |
| Plague | Hepatitis |
| Shigellosis | Influenza |
| Smallpox | Meningitis |
| Typhoid fever | Pneumonia |
| Typhus | Tuberculosis |
| Yellow fever | Whooping cough |

sis during the period 1900–1904 characterized our present population of 225 million, all the U.S. deaths from World Wars I and II, Korea, and Vietnam would be surpassed in one year and 10 days.

Should this concern us for the post-attack period, when we know that the mortality rate of tuberculosis has fallen below 1/200 of the 1900–1904 figures? In 1978 there were only 2830 deaths, and 28,521 new active cases in the United States. The percentage of the population who are positive reactors has also dropped dramatically to 4 to 8 percent of all tested.

But the bulk of this decline was achieved without the aid of drug therapy. By 1944, when the modern era of effective anti-tuberculosis drug treatment began, the mortality rate had dropped to 43.4 per 100,000, less than 24 percent of its 1900–1904 rate. This change was largely attributable to improved socioeconomic circumstances, particularly since the incidence and mortality of tuberculosis rose and fell frequently in the past with altered societal conditions, especially in times of war (see the figure on p. 228).

During World War I, mortality increased 218 percent in Warsaw, reaching a rate of 974 per 100,000 in 1917. The highest incidence in all European cities in World War I was in Belgrade; the rate in 1917 reached 1483 per 100,000. During World War II the death rate rose 268 percent in Berlin, 222 percent in Warsaw, and 134 percent in Vienna. An analysis of 2267 chest roentgenograms at the Dachau concentration camp at the time of liberation




*Tuberculosis death rate for England and Germany, 1900–1924. (From Mitchell, 1967.)*

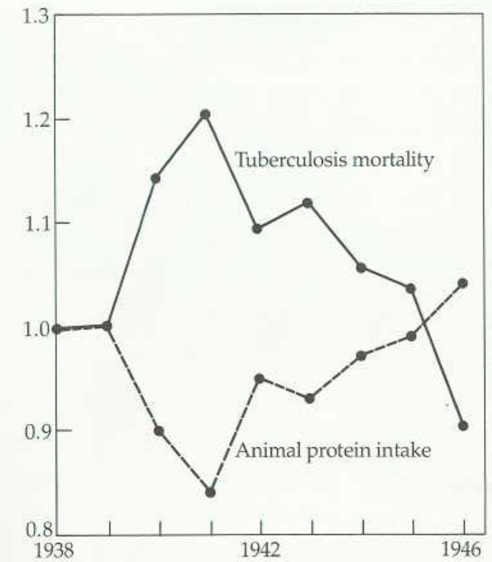
showed that 28 percent had evidence of tuberculosis, of which nearly 40 percent were "far advanced."

In the aftermath of nuclear war, all the factors that increase susceptibility to and spread of infection in general would be particularly applicable to tuberculosis. The destruction of housing, lack of fuel, shortages of food, medicine, and clothing, and a sustained period of labor and struggle would create precisely the setting in which tuberculosis has flourished in the past.

Nutritional status traditionally has been associated with an increased incidence and mortality from tuberculosis. More than 20 different studies have shown the relationship between food quality and tuberculosis, most striking during wartime. Animal protein is particularly important (see the figure opposite).

Fewer Americans have been exposed to tuberculosis today than ever before. Numerous examples of catastrophic epidemics among largely unexposed populations have been reported. South African troops in World War I had a mortality rate of 1745 per 100,000 from tuberculosis, while British troops had a rate of only 11 per 100,000. When Saskatchewan Indians were removed from nomadic to reservation life around 1880, their death rate from tuberculosis reached 9000 per 100,000.





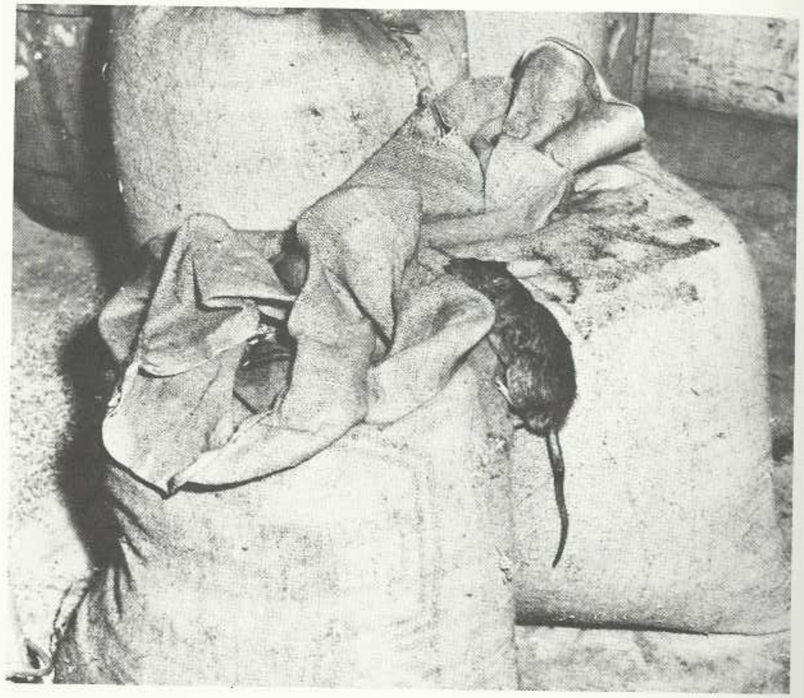

*Tuberculosis mortality and animal protein intake for England and Wales, 1938–1946. (Adapted from Mitchell, 1967.)*

In the United States from 1804 to 1808, eight of the top ten causes of death were infections (tuberculosis was number 1), accounting for 1526 deaths annually per 100,000 of population. From 1900 to 1904, six of the top ten causes of death were infections (tuberculosis was number 2), with 964 deaths per 100,000. By 1945–1949, only four of the top ten were infections (tuberculosis was number 7), accounting for 154 deaths per 100,000, just 10 percent of the deaths resulting from infection 140 years before.

## Plague

Plague has been a known source of epidemics for the past 3500 years. In the twentieth century alone, more than 12 million deaths have been attributed to it.

Plague is endemic among wild rats in the 11 westernmost states. More than 30 types of wild rodents and rabbits have been found infected. Cats and dogs can be infected experimentally, naturally, or when they ingest infected rodents. Human contact with wild rodents is almost exclusively the source of plague cases in the United States, which accounted for 13 cases during 1981, 4 of which were fatal.



*Rats in bags of grain. Plague is endemic among wild rats in the 11 westernmost states. (United Press International.)*

A nuclear attack would create almost ideal conditions for breaching the "thin protective wall" against plague. Large areas of the western United States now relatively devoid of inhabitants might receive an influx of refugees from threatened or devastated urban areas. Relocation plans call for enormous increases in the population of many remote regions. Humboldt County, California, for example, would experience a fivefold or more increase in population. Millions of urban refugees, unable to obtain shelter in existing dwellings, would build earth-covered "expedient" shelters in undeveloped areas. Such shelters might provide good fallout protection, but they would create ideal conditions for transmission of plague from rodents.

Rodents are relatively resistant to plague, developing chronic infections, which function as a reservoir for the disease. Radiation would increase their susceptibility, as well as that of humans. High mortality among wild rodents then would help spread the



disease to nearby humans: as the rodents die, the more resistant fleas would leave them and search for other hosts.

Once radiation had subsided in leveled cities, many survivors would head back hoping to reclaim whatever possessions might be found and to search for family members and friends. Over 90 percent of housing would be destroyed in a nuclear attack; there would be crowding in the remaining buildings. Conditions in the damaged cities would be favorable for the spread and propagation of plague. The rat population would increase because harborage and food for rats would be available.

A major danger comes not only from bubonic plague transmitted by domestic rats, but from human-to-human pneumonic plague. Under post-attack conditions, radiation and stress would raise the conversion rate of bubonic to pneumonic plague to 25 percent.

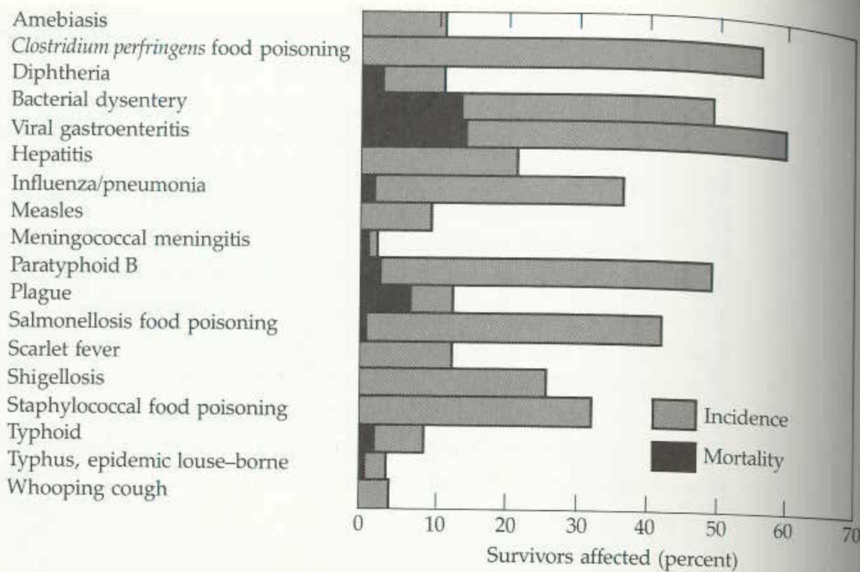
## Quantitative Estimates of Infection in the Post-Attack Period

In the aggregate, deaths from communicable diseases among the survivors might approach 20 to 25 percent. Estimates of both the incidence and the mortality of infection in the post-attack world would vary widely for different diseases (see the figure on p. 232).

A computer simulation of the effects of a single nuclear explosion 9 miles south of New Orleans calculated that in the absence of medical countermeasures, 35 percent of the survivors would die from infectious diseases in the first year post-attack. This expected high mortality rate from communicable diseases would be ten times more than the normal death rate from noncommunicable diseases such as heart disease and diabetes, which would claim only 2.5–3 percent of the survivors. Equally, it would far surpass the cancer mortality, estimated at a few percent or less.

## Conclusion

Numerous factors point to an increased risk of serious epidemics in the post-attack environment. These include the effects of irradiation, malnutrition, and exposure on the susceptibility to infection. Furthermore, unsanitary conditions, lengthy shelter stays,




*Disease incidence and mortality among U.S. populations exposed to nuclear weapons effects (with no medical countermeasures).*

and insect population growth would facilitate the transmittal of disease. Depleted antibiotic stocks, physician shortages, laboratory destruction, and societal disorganization would render countermeasures largely ineffectual.

Although it is impossible to determine the extent of such "catastrophic" epidemics, it is certain that infection would pose a substantial threat to the health and recovery for all those injured by blast, heat, and radiation, and that the resources to grapple with this threat would be totally inadequate.

## References

Abrams, H. L., and W. E. Von Kaenel. 1981. "Medical Problems of Survivors of Nuclear War: Infection and the Spread of Communicable Disease." *New England Journal of Medicine, 305:* 1226–1232.

Center for Disease Control. 1980. "Annual Summary." Morbidity and Mortality Weekly Report 28 (September).



Glasstone, S., and P. H. Dolan, eds. 1977. *The Effects of Nuclear Weapons,* 3rd ed. Washington, D.C.: U.S. Department of Defense and U.S. Department of Energy.

Haaland, C. M., C. V. Chester, and E. P. Wigner. 1976. *Survival of the Relocated Population of the U.S. After a Nuclear Attack.* Springfield, Va.: National Technical Information Service, 20–1. (Defense Civil Preparedness Agency report no. ORNL-5041.)

Johnson, D. R., M. L. Laney, R. L. Chessin, and D. G. Warren. 1978. *Study of Crisis Administration of Hospital Patients; and Study of Management of Medical Problems Resulting from Population Relocation.* Research Triangle Institute, RTI/1532/00-04F (September). Washington, D.C.: Defense Civil Preparedness Agency.

Mitchell, H. H. 1966. "Plague in the United States: An Assessment of Its Significance as a Problem Following a Thermonuclear War." Santa Monica, Calif.: Rand Corporation. (U.S. Atomic Energy Commission report no. RM-4868-TAB.)

Mitchell, H. H. 1967. "The Problem of Tuberculosis in the Post-Attack Environment." Santa Monica, Calif.: Rand Corporation, RM-5362 (June).

Sullivan, R. J., K. Guthe, W. H. Thoms, and F. L. Adelman. 1979. *Survival During the First Year After a Nuclear Attack.* Washington, D.C.: Defense Civil Preparedness Agency, 140. (Federal Emergency Management Agency report no. SPC-488.)

U. S. Federal Emergency Management Agency. 1979. *Analysis of Packages Comprising Program D-Prime.* Washington, D.C.

U. S. Federal Emergency Management Agency. 1980. "Material for the Record." U.S. Congress, Senatorial Hearing on Short- and Long-Term Health Effects on the Surviving Population of a Nuclear War, 96th Congress, 2nd Session, June 19.

Voors, A. W., and B. S. H. Harris. 1970. *Postattack Communicable Respiratory Diseases.* Research Triangle Institute, R-OU-493 (November), pp. 7–25. Sponsored by the Office of Civil Defense.