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Chapter One

INTRODUCTION AND OVERVIEW

Leonard Berkowitz

Leonard Berkowitz is the Vilas Research Professor Emeritus in Psychology at the University of Wisconsin-Madison. Greatly concerned with the application of psychological principles and theories to everyday social issues, he is widely known for his writings and laboratory research on the determinants of aggressive behavior. The author of six books in the field of social psychology and also the former and founding editor of the annual series Advances in Experimental Social Psychology, he also has been president of the International Society for Research on Aggression, has been elected to the American Academy of Arts and Sciences, and has received a number of awards for his contributions to social psychology.

Very early in the morning of April 26, 1986, Reactor No. 4 on the Chernobyl Nuclear Power site near Kiev exploded during a safety test, destroying the unit’s nuclear core and starting an intense blaze that raged for about ten days. A massive amount of radioactive material was released into the atmosphere during this period which was spread by winds over large areas of Ukraine, Belarus, Russia, and beyond. The Soviet government took more than a day to provide any information about the accident, and even then initially minimized the seriousness of the occurrence. But the event’s aftereffects were horrendous. A month after the accident, the daily release of radioactive substances was still greater than the total amount released by the nuclear accident at Three Mile Island in Pennsylvania in 1979. An estimated half a million persons were forced to leave their homes; almost half of them never returned. Both the residents of the areas afflicted by the fallout and the cleanup workers assigned to reduce the contamination received substantial doses of radiation during this period. Many of the catastrophe’s adverse consequences persist.

Chernobyl: The Event and Its Aftermath provides a well-balanced and comprehensive
examination of the causes and consequences of this disaster. Experts from the broad spectrum of fields bearing on the accident and its aftereffects—(in alphabetical order) history, literature, medical genetics, political science, psychology, nuclear engineering, radiation biology, and social work—consider why the nuclear explosion occurred, what the physical and psychological effects were on its victims, and what steps government officials took (or should follow) to cope with the immediate and long-term consequences of the catastrophe. Adding to the breadth of this coverage, the writers are truly international in their background and perspective.

It is now almost two decades since the Chernobyl disaster occurred, but the event is still very important and for a number of reasons. Perhaps of most immediate relevance, with the 440 or so nuclear reactors in operation around the globe producing about one-sixth of the world’s power (according to the International Atomic Energy Agency), the international community obviously has an abiding interest in the safety and future of nuclear power generally. Rising oil prices, anticipated declines in the availability of petroleum resources, and the mounting worries about atmospheric pollution have all brought about a renewed attention to nuclear power.

The United States undoubtedly will experience a great deal of controversy in the near future about the reliance, even in the short term, on nuclear energy. Fueled to a considerable extent by the Chernobyl disaster, this debate may be at a particularly high level of intensity judging from the dispute now swirling about the question of what to do with the nuclear waste that has already been accumulated and the opposition that has been generated by the Bush administration’s announced plans to favor the building of new nuclear plants. Although the U.S. has the largest commercial nuclear power program in the world, with 103 licensed nuclear power plants in operation (as of 2002), only about 20 percent of its electricity is produced in this manner, and no new nuclear plants have been built since 1979 when the Three Mile Island accident in Pennsylvania occurred. (See Moore’s chapter in this book for a report on some of the effects of this accident.) However, as the newspaper *USA Today* observed in the fall of 2004, “… soaring energy costs, worries about energy dependence, and growing fears of global warming have combined to revive a once-doomed industry…” Voicing the increasing concerns about energy shortages, the current national administration has recommended a greater use of nuclear-generated energy, and three utility consortiums in this country have filed applications with the Nuclear Regulatory Commission to allow the first stages in planning and possibly constructing new plants.

The pressure for renewed attention to nuclear power appears to be more explicit in the United Kingdom than here. Six months ago, the British government’s chief scientific advisor held that it will soon be necessary to actively review the need for nuclear power generation if
the country is to reach its targets for reducing greenhouse gases. Prominent journalists in that
country have been even more forceful, and along with a number of academic researchers, at
least one of them argued that only nuclear technology can adequately cope with the forthcoming
energy shortage resulting from the nation’s dwindling supply of North Sea oil and gas.

Critics, of course, have disputed the wisdom of pro-nuclear policies, maintaining that the
danger of an accident and the widespread damage that would occur is much too great. In the
words of one environmentalist, “The nuclear option is fraught with environmental, human
health, financial, and terrorism risks” (cited in article by Alan Cowell, *N.Y. Times*, Oct. 9,
2004).

This book presents arguments for both—and indeed, for all—sides of this debate. Written
primarily for an audience of nonspecialists and avoiding a strong one-sided position on the
issue of nuclear power, it can help interested readers form sound and well-informed opinions on
the subject of nuclear power.

A number of the papers in this volume might also aid in coping with a nuclear disaster
should that ever occur again. Nuclear engineers in this country contend that with the technologi-
cal advances that have been made, there is now exceedingly little chance of a major nuclear
accident with significant radioactive contamination. Critics are not necessarily assured. Added
to the concerns about the inherent safety of nuclear power plants is the danger of a terrorist
attack. However remote such an occurrence might have seemed several years ago, the events of
September 11, 2001 have demonstrated all too clearly the substantial threat to a nation’s well-
being posed by even small groups of people who are determined to harm countries they hate.

One of the most important lessons taught by the Chernobyl disaster has to do with its long-
lasting consequences. The Chernobyl story is by no means over, even as the initial events re-
cede into the past. A UN-sponsored investigative group especially concerned about the effects
of the radioactive fallout on health noted that life has been affected in the afflicted communities
“for decades to come.” They quoted “conservative estimates” predicting a 4- to 5-fold increase
in the rate of thyroid cancers in the coming years in those young people who were exposed to
the fallout of radioactive iodine at the time of the incident. But where there is relatively little
argument about a radiation-induced rise in thyroid cancers, the contention that other types of
cancer are also produced by the fallout is much more controversial. Much more has to be
learned about, among other matters, the health consequences of a very long internal exposure to
radionuclides ingested from contaminated foodstuffs. Long-lived radioactive isotopes of cesium
and strontium present in the fallout from the explosion migrate through the food chain and ac-
cumulate in the various forms of meat, milk, and dairy products. Currently there simply is no
experience or data to help us sort out the benign from the serious potential consequences of this prolonged exposure.

A truly complete understanding of all of these consequences and issues cannot be gained, however, if we look at what has happened only through a “hard science”-oriented prism. As important as it is to know what went wrong technically, what engineering steps can be undertaken to prevent other such accidents, and how radiation affects one’s physical health, the Chernobyl story also demonstrates the need for a broad-ranging perspective. Science and technology, substantially guided by carefully collected research findings, are often viewed as isolated from the less well-defined goings-on of governments and peoples. But Chernobyl, like other technological disasters, demonstrates that this seeming separation is illusory. The nuclear plant operated and malfunctioned within a particular socio-cultural and political context that did much to govern the decisions of those who planned and designed it and those who controlled it on a daily basis. A variety of historical, political, and social factors then influenced, and continue to affect, how the people in the afflicted and surrounding areas have reacted and what kinds of traumas they have suffered. Looked at another way, one can say that the causes and consequences were shaped by often subtle interactions among many of the diverse social systems within these societies. All in all, the lessons of Chernobyl can be spelled out fully only by combining the insights of experts across the various disciplinary lines. This work, *Chernobyl: The Event and its Aftermath*, seeks to portray the complexity of the Chernobyl disaster and its many different consequences through the adoption of such a broad ranging multidisciplinary perspective.

Accidents or terrorist assaults could produce a calamity comparable to the Chernobyl explosion in the damage and destruction done to lives and property even if it is not identical in its details. Information gleaned from Chernobyl could help mitigate these terrible consequences. The reactions of the people in the afflicted regions following the Chernobyl disaster show how rumors form and spread, inflaming anxieties. These aftereffects also suggest what kinds of information are needed and are best disseminated, how informal channels of communication should be utilized to transmit this information quickly, and how important it is for both official and unofficial community agencies to take ameliorative actions and what these remedial steps might be. Chernobyl also teaches us the very important human lesson about the ways in which the persons who are either directly or indirectly affected by any calamity of this magnitude and seek to cope psychologically with the threats they see around them, and how the world community can most effectively help.
The Book’s Contents

Very generally speaking, in their ordering, the chapters tell the story of the disaster and its consequences. The volume begins with a look at the cultural context within which the Chernobyl nuclear power plant was built. Michael Beissinger’s contribution holds that Soviet society had developed a broad set of attitudes, a culture of irresponsibility, permitting or even favoring environmental abuse. At least partly because of Stalin’s desire for rapid industrialization at any cost, production was the primary concern, and there was little interest in the environmental impact of many industrial and organizational practices or even in their safety.

The next two chapters of the book then turn to the technical aspects of what had happened at Chernobyl and the overriding issues of the dangerousness of the Chernobyl reactor and of nuclear power more generally. The questions most often voiced about Chernobyl probably are: “Could that nuclear explosion have happened here?” and “Can it happen again?” In his chapter, Michael Corradini answers the first query with an emphatic “no” but is tentative in responding to the second question. As he puts it, Chernobyl was the result of an inherently unsafe engineering design and improper testing procedures. The former speaks to technology, the latter to human judgment. According to Corradini, the difference between Chernobyl and our own nuclear power accident at Three Mile Island in 1979 was that, while bad judgments were made in both incidents, the better design of the Three Mile Island reactor prevented release of radioactive debris, thus avoiding subsequent environmental and human health problems. He further argues that none of the conditions—either human or machine—leading to the Chernobyl disaster are likely in the United States. Moreover, Corradini also contends that all old Soviet RMBK reactors, such as those on the Chernobyl site, have been modified so that these conditions are no longer likely in the former U.S.S.R. either.

However, Arjun Makhijani and Scott Saleska follow with a less sanguine view of the risks of nuclear power. Questioning the claims that some reactor designs are “inherently safe,” they maintain that nuclear technology is very complex and that in seeking to eliminate now-recognized accident possibilities, plant designers might well be inadvertently introducing unforeseen problems. In these writers’ view, “safety uncertainties can never be fully resolved in advance,” and years of operating experience are required if the right decisions are to be made about the overall designs as well as critical details. Makhijani and Saleska identify a number of reactor accidents that have occurred in the U.S. and abroad, and then examine the Chernobyl disaster in some detail. For them “the most important and tragic lesson” of this accident is that while incidents on the scale of this catastrophic occurrence “are more probable in the former
Soviet Union and Eastern Europe,” they are “also possible elsewhere.”

We now come to the disaster itself, focusing first on the political fallout. In his chapter, David Marples relates how, after the accident, it took months and even years for people to rally against the secrecy and deception employed by the Soviet authorities in the event’s immediate aftermath. He then describes the public reactions and the political consequences that followed. Interestingly, as Marples reports, these developments were quite different in Ukraine and Belarus. Where there was “no dissension” between the Ukrainian government and its political opposition as to the need to remedy “the severe impact of the accident on society,” the much more autocratic Belarusian government regards Chernobyl as “a dangerous issue” that it wants “put to rest.”

Volodymyr Tykhyy also discusses public and official reactions to the catastrophe, although he concentrates on events in Ukraine. After summarizing the immediate responses of the highly centralized “command and control” system in the U.S.S.R., he tells how environmental groups, liberal elements, and political figures in Ukraine mobilized support for the victims of the disaster, and describes key aspects of the legislation passed by the Ukrainian parliament to aid these people. Efforts such as these inevitably encounter problems, however, and Tykhyy also gives us a picture of some of them, ranging from various financial difficulties to official corruption and even abuses perpetrated by beneficiaries of the legislation.

Jennifer Tishler’s chapter, coming next, enriches our understanding of what the Chernobyl calamity means to its victims. Where Marples and Tykhyy concentrate largely on official and political reactions to the disaster and its aftermath, Tishler speaks of the occurrence’s significance to ordinary persons as seen by four writers—a playwright, a poet, the author of a short story, and a novelist. They obviously didn’t view the disaster in exactly the same way, partly because they wrote at different times and the event’s meaning for the affected populations had changed to some extent with the passage of years. The initial literary response, Tishler says, was to “get to the ‘truth’ of the accident” and determine “who was to blame,” although for the playwright, the first author considered, the catastrophe also highlighted the horrors of nuclear war. For the poet, however, the next writer discussed, blaming was much less important than the victims’ loss and suffering. The short story author paints an even darker picture. Writing about a village dying in the aftermath of the nuclear explosion, his message (in Tishler’s words) was that “Chernobyl is not the cause of man’s inhumanity to man, but brings it into sharper relief.” The last writer taken up builds on her interviews with people afflicted by the accident to go movingly beyond “reported facts to human memory, giving voice to those behind the nameless statistics,” although she recognized memory’s limitations. Tishler makes it clear that the
four are not journalists in the usual sense of this term. Their work was far more universal, literary endeavors rather than merely a record of what happened. Literature, Tishler tells us, “faces up to the catastrophe, ‘measures its human consequences, and refuses to be consoled.’”

The following three chapters offer a fairly close examination of nuclear radiation and its health effects. Michael Patrick starts this section with a “primer” introducing nonspecialists to the basic concepts and foundation principles of radiobiology. After briefly spelling out the fundamentals of radioactivity, he discusses how radiation dosages affect biological processes including genetic coding. He also points out that we are all immersed in naturally occurring ionizing radiation—and have been ever since life emerged on the planet. The individual dose rate of natural radiation the average inhabitant of Earth receives is about the equivalent of the radiation produced by the naturally occurring $^{40}$potassium that is encountered by eating four bananas per week. To be sure, man-made radiation has increased during the 20th century, but this increase is primarily due to the broad application of medical diagnostics. According to data from the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), other major sources of radiation (e.g., nuclear power, nuclear weapons testing and Chernobyl) have contributed to less than 0.1 percent of that increase.

Nonetheless, exposure to large amounts of radiation is lethal, as the deaths among the Chernobyl plant personnel and the “liquidators” sent to extinguish the fires at the plant show so tragically. The research into the aftereffects of the atomic bombing of Japan also points to the long-term adverse consequences of relatively severe radiation exposure. Surveying the findings of these investigations, Kelly Clifton’s chapter relates that in Japan there was a greater-than-usual chance of blood cancers five to eight years after the bombing. And then, some years later, according to the advisor to the UN-commissioned investigation we cited earlier, the bombing victims had an “excess” of solid cancers followed by a rise in the rate of cardiovascular disorders. Can we expect exactly the same outcomes in the Chernobyl region since, as Clifton reports, the radioactivity produced by the nuclear explosion was of a different nature? Perhaps because of this difference, United Nations agencies have not obtained any unequivocal evidence that the radiation to which many of the Chernobyl area’s inhabitants were exposed did in itself result in inordinately high levels of blood cancer in these people. However, even so, relatively substantial levels of radiation can have other unfortunate consequences. Clifton’s chapter tells us that by ten years after the accident an examination of the health records of a large sample of Russian male liquidators who had been exposed to heavy radiation doses indicates there were significantly more solid cancers of all kinds, and especially intestinal cancers, than were found in non-radiated “control” Russian men. (He also warns us, though, that there are doubts about the adequacy of the cancer rate figures in the “control group.”) Yet another examination of a
large group of Russian liquidators found that the level of radiation dose experienced was positively associated with the death rate due to cardiovascular disorders. Even more striking, it is now widely agreed that children residing in the contaminated areas were all too prone to develop thyroid cancer. As Clifton explains, since these youngsters lived in an area deficient in iodine, their thyroid glands tended to absorb a good deal of whatever iodine was present. After the nuclear plant exploded, this was apt to be the radioactive $^{131}$I, and as a consequence, there was a rise in the rate of thyroid cancer in young children. But still, although a relatively small fraction of those living in the contaminated areas had received doses sufficient to cause permanent debility or even death, or perhaps a heightened susceptibility to future cancerous or non-cancerous diseases, after a thorough examination of the data Clifton maintains that it is uncertain whether low to moderate doses of radiation have baleful consequences. Indeed, he argues that because of the low total doses received by most inhabitants of the controlled zones “it is unlikely that [they] will have detectably increased risks of radiation-related benign or malignant diseases.” All in all, he concludes that there are as yet many questions about the long-range effects of the Chernobyl disaster that can only be answered by large long term systematic investigations.

Colleen Moore’s chapter considers the nuclear reactor accident at Three Mile Island (TMI) in Pennsylvania in 1979, as well as the Chernobyl explosion. Since the present very brief survey of the papers in our book, particularly Clifton’s chapter, has already gone into this latter disaster, all we will say about Chernobyl at this time has to do with its possible psychological effects (a matter considered at some length by later papers in this volume). As part of her research review, Moore summarizes studies comparing children born shortly after the nuclear explosion and who lived in contaminated areas with other youngsters of a comparable background who did not live in regions afflicted by radioactive fallout. Several of these investigations found that children in the radiation-exposed group were more likely to exhibit impaired intellectual development and speech and language disorders. It’s not clear, however, how much of this difference is due to the radiated families’ greater stress and anxiety, although one team of researchers suggested that at least some of the cognitive deficiencies resulted from the former children having been irradiated in utero. Whatever the exact cause(s) of these mental problems, Moore’s research survey documents the substantial psychological impact of the nuclear disaster and its aftermath on the afflicted population.

As for the TMI incident, experts report that this event had released only a small fraction of the amount of radiation let loose by the Chernobyl disaster (as was mentioned before), and official pronouncements maintained that the chances were “virtually nil” that the Pennsylvania occurrence had any adverse health effects either in the short run or over the long term. Moore
expresses some misgivings about conclusions such as these based on assumptions regarding what radiation dosage is necessary for biologically injurious effects. As she points out, over the years, scientists have lowered the dosage level at which biological damage is said to arise, and she also tells us that researchers disagree as to whether there was an increased risk of cancerous diseases in the TMI area. However, there is much less disagreement about the accident’s psychological consequences. Discussing these stress-induced effects experienced by children and grownups following the incident, Moore reminds us that they should not be dismissed as “all in the head,” as imaginary ailments. Psychological stress can have a considerable influence on physical health.

The next several chapters in our book expand on the psychological and social consequences of the nuclear disaster in Chernobyl. In the first of these, Ann Speckhard looks at this event (and other incidents as well) from the perspective of technological mishaps, especially those involving the spread of hazardous substances. After noting how these calamities differ from natural catastrophes, she goes on to examine the psychological and social mechanisms operative in toxic disasters and discusses ways of alleviating or even averting the experienced distress and harmful mental health consequences that typically follow in the wake of these events. The writer illustrates many of her points by quoting from her interviews with people who had been directly affected by the technological incidents she discusses. She particularly emphasizes the very significant role played by how the area’s inhabitants process the information they receive about the perceived threat. Their strong fear often causes them to focus narrowly on what they believe is the danger before them so that they fail to consider other important matters that are not immediately apparent at that time, and even cling firmly to their possibly erroneous initial ideas. Another common reaction, Speckhard notes, is to hold some persons responsible for what had happened, and as a consequence, to become mistrustful of authorities or even angry with them. But she gives special attention to the stress-produced emotional reactions following the hazardous events. Along with other discussions of posttraumatic stress disorders, Speckhard describes the experience of intense, anxiety-provoking flashbacks—vivid images of the threatening even that come to mind in an involuntary and intrusive manner. More than this, though, she believes it is also important to recognize the role of “flash-forwards,” intrusive images of horrific events expected to occur in the future.

Yuri Shvalb’s chapter, which follows, has to do with the psychological adaptation patterns the residents of the Chernobyl region had developed in response to the threat of radioactivity. He notes that people confronted by threatening ambiguous circumstances, as often is the case in technological accidents, frequently develop a set of beliefs about what is happening—views that
Shvalb terms *myths*—that tell them how to act under the circumstances. The author regards the public’s thoughts about the action chosen as instances of magical thinking in that there is “no rational linkage” between the behavior undertaken and the expected results. On surveying a fairly large representative sample of Ukrainians about the Chernobyl calamity, he found that most adults and children believed they can still feel the accident’s effects and that they got sick “more often” as a consequence. The “myths” they developed about what to do under the conditions they thought existed can be classified in terms of two underlying dimensions: one in which the beliefs vary in the degree of their optimism vs. pessimism about the event, and the other being a continuum of how active or passive the person should be in responding. The “take it easy” myth, for example, advocates passivity under the assumption that nothing can be done about the radioactivity and that if people think the threat is not there, maybe the danger will go away. A still more disturbing belief pattern can be located further into the lower right quadrant and holds that one should try to minimize the dangers of radiation—but that this will not help much.

The final two chapters conclude with a look at the relatively institutionalized international mechanisms developed by the world community as well as the directly affected governments to ameliorate the Chernobyl catastrophe’s adverse aftermath. Oksana Garnets’ chapter outlines the development of a network of Community Centers, established by the United Nations Social and Economic Council (UNESCO) in 1994, that works to meet the psychosocial needs of individuals, families, social groups and the communities as a whole. Although these Centers were initially intended to focus on lessening the residents’ radiation-related fears and help them adapt to the new circumstances of their changed lives, these Centers now increasingly function as organizations facilitating economic and community development. In the broadest terms, they are helping to educate the citizens of now “post-totalitarian” countries to become more self-responsible and effective members of a more democratic society.

Norma Berkowitz, in her chapter, summarizes the various ways in which the United States is playing a part in mitigating the effects of the Chernobyl disaster. In what is perhaps the most dramatic of these efforts, American tax dollars, together with contributions from Europe and Ukraine itself, are being employed for the construction of a gigantic new concrete shelter over the ruined nuclear plant that will replace the present decaying “sarcophagus” shield. Then too, the U.S. Agency for International Development and the Department of Energy have funded research programs, often as partnership projects with Russian and European institutions. More than this, and certainly not to be slighted, voluntary agencies in the United States have taken it upon themselves to provide humanitarian aid to Chernobyl-affected communities and groups. She discusses the activities of three such agencies as an example. But going beyond the Ameri-
can efforts, Berkowitz also looks at the important role of the United Nations in assisting the countries afflicted by the Chernobyl catastrophe. There is also the vital, and controversial, matter of how the accident and the ensuing radiation had affected the health of the residents of the contaminated areas. Adding to the discussion of these effects that can be found in other chapters in this book, Berkowitz also addresses these consequences and considers as well the impact of psychosocial stresses, the poor economic situation, inadequate health care, and the poor sanitation infrastructure in the afflicted regions.
Chapter Two

CHERNOBYL AND THE CULTURE OF ENVIRONMENTAL IRRESPONSIBILITY

Mark R. Beissinger

The Chernobyl nuclear accident was the worst nuclear accident in world history, releasing ten thousand times the level of radioactivity produced by the next worst nuclear mishap. In all, seven hundred and fifty thousand acres of land and forest were contaminated, and radiation was dumped on 3,500 cities and villages; it is estimated that five hundred thousand people were exposed to significant doses of radiation, and 2.2 million people received some radiation from the accident. In short, this was an environmental disaster on a singular scale. The very scale of Chernobyl and its accidental origins present a problem for those of us who would try to learn from it. For one thing, events of this magnitude seem to defy the kind of systematic explanation from which we might draw broader, transferable lessons, since the scope of the disaster can only be measured on a scale completely different from that we usually employ in judging other misfortunes. It is much like trying to draw lessons about terrorist violence from the Holocaust. Moreover, Chernobyl was an unintentional event; no one wanted it to happen, and while specific actions of negligence brought it into being, it is difficult to identify the larger chain of responsibility implicated within it. How does one learn lessons from a disaster of singular scope that occurred unintentionally?

In this essay I try to reconcile the tension between intentionality and unintentionality in the
Chernobyl nuclear disaster by addressing two issues. First, I will argue that Chernobyl needs to be understood as part of a broader cultural pattern of environmental abuse, and in doing so, I want to focus on the idea of culture as a set of rules. It is sometimes said it is the setting of the rules that really matters, and everything after that follows. Yet, Chernobyl occurred in part because those running the power station set aside the rules. Essentially, when we talk about rule-guided behavior, we are talking about what social scientists refer to as “culture.” The famous philosopher Ludwig Wittgenstein wrote about language as a form of rule-guided behavior—rules that we sometimes are not even aware of that guide us in our behavior and that we use as a form of convention to signify shared meanings. And so it is with culture as well. Culture consists of a set of rules and expectations that guide our behavior. It includes not only formal rules, but also informal rules and conventions—most of which usually take as their point of reference the formal rules. And it is these formal and informal rules that make action meaningful. In speaking of “the culture of irresponsibility” in the former Soviet Union toward the environment and human safety, I am essentially referring to a set of rules—formal and informal conventions—that led to a larger, repeated pattern of abuse. Chernobyl was a singular accident. But it was very much the product of rule-guided behavior, and this same rule-guided behavior was responsible for many other environmental disasters whose consequences remain extant throughout the former Soviet Union today.

Rules, Subversion of Rules, and the Soviet Nuclear Industry

Viewed in this way, the natural question that the Chernobyl accident raises is why this culture of irresponsibility toward the environment and human safety issues came into being in the first place and reproduced itself over time. (Indeed, as such events as the Kursk submarine disaster or the massive oil pipeline spills in the Pechora River region indicate, this culture of irresponsibility in Russia has survived well into the post-Soviet era). As we will see, there were many formal rules in the Soviet Union that were meant to protect against environmental damage and safety violations, and the engineers who started the Chernobyl nuclear accident on April 26th ironically were carrying out a safety test when they launched the accident. Actually, their violation of safety rules in conducting their test was itself due to rather widespread informal conventions within Soviet industry. Environmental irresponsibility in the Soviet Union—including the Chernobyl accident—was produced not by the absence of rules, but rather by the internalization of a set of production practices and expectations, ways of meeting the rules and of getting around the rules. In other words, the lesson that we need to take away from Chernobyl is that
prevention of disasters like Chernobyl is only partly a matter of setting the rules or about the design of equipment. More importantly, it is a matter of setting up cultural expectations and incentive systems that stimulate people to observe responsible behavior toward the environment—that is, to cultivate a culture of responsibility.

How do we know that the Chernobyl accident arose from rule-guided behavior and was not an isolated incident? For one thing, there is evidence that points to a widespread pattern of violations of environmental and safety procedures throughout the Soviet Union. The Chernobyl accident can be ascribed in part to technical flaws in the design of the nuclear power plants in the Soviet Union, as Corradini argues in Chapter 3, but this catastrophe was not solely due to technical deficiencies. The USSR had 53 nuclear power stations in operation at the time of its collapse. Many of these are still in operation today, including plants in Russia, Lithuania, and Armenia built on the Chernobyl design. (The last-mentioned of these, the Medzamor plant outside Yerevan, is located in an unstable earthquake zone. See Gureghian, 1994). The flaws in the design of the Chernobyl reactor were a matter of mass production, not a singular error. But more importantly, analogous types of design flaws were rampant throughout Soviet industry. The plant that built the Chernobyl reactor—the Atommash plant in Rostov—itself was mistakenly built below a hydroelectric dam across the Don River, and as a result, experienced a rather severe industrial accident. Because of the dam, the water levels in the soil surrounding the plant began to rise, causing the foundation of one of the walls of the plant to collapse suddenly, and leading to a major industrial accident in July 1983 (Pryde, 41). Thus, ironically, those who were responsible for the design flaws at Chernobyl were themselves the victims of an accident stemming from design flaws at their own plant.

Second, within the Soviet nuclear industry more generally, there was a widespread pattern of environmental abuse and violation of safety procedures. According to a report by Russia's Minister of Ecology in 1992, about one hundred thousand people in Russia live in areas with an “unfavorable radioactive situation” (Transition, vol. 5, no. 1, January 1994, p. 19). Most of these people live outside the Chernobyl zone—in areas in which other nuclear accidents had occurred or in formerly closed cities involved in Soviet nuclear weapons production. The most serious of these accidents was the infamous chemical explosion that took place at a nuclear waste dump in the village of Kyshtym in Cheliabinsk province in the Urals Mountains in fall 1957—which the Soviet government tried to keep a secret, but eventually admitted in 1989. The explosion spread 2 million curies of radiation over a 1,000-square kilometer area and led to the evacuation of about ten thousand people from the area. The area remains a closed zone. How did the explosion take place? Here is the description by the person who was in charge of the nuclear reprocessing plant in Kyshtym at the time:
Radioactive wastes . . . were dumped into a series of stainless steel and concrete tanks located slightly more than a mile from the plant . . . To keep the wastes from becoming explosive due to a natural chemical reaction . . . they were cooled by a coil of water tubing along the interior wall of each tank. The designers of the tanks did not provide a mechanism for repairing the tubes in the event they failed . . . Sometime in 1956, the tubing in one of the tanks began to leak and was then shut off . . . Faulty calculations by scientists . . . indicated that despite the failure of the cooling tube, the wastes were stable . . . As a result, more than a year lapsed with little or no effort to devise a means of repair. During this period, the wastes began to dry . . . and highly explosive nitrate salts and acetate collected at the surface. By chance . . . a control device in the tank produced a spark which detonated the salts, and the resulting explosion obliterated the tank and all that it contained (Medvedev, 1990, 284).

In short, carelessness, recklessness, and little attention to safety caused this nuclear accident as well—the worst known accident in defense applications of nuclear technology in the world. The pattern of nuclear irresponsibility, though, was much broader than this. As we now know, the Soviet navy practiced extensive dumping of nuclear waste from submarines into the Pacific and Arctic Oceans, a subject of intense controversy with Norway and Japan. In former defense plants connected with the production of nuclear weapons, safety procedures were frequently violated—as they were in Chernobyl. At nuclear defense plants in Cheliabinsk province, for instance, radioactive water was on many occasions dumped into open containment ponds, where it continues to sit today, causing a significant health hazard to the local population. Some 600 miles of the Yenisei River downstream from the Krasnoiarsk-26 military facility were heavily contaminated with radiation, since in the past water from the cooling towers of the plutonium-producing plant went straight into the river.

In Georgia, 48 members of the Georgian military in the mid-1990s developed radiation sickness because of the lax precautions that the Soviet army took with regard to radioactive material, much of which it left behind it when it withdrew from the republic (Khetsuriani, 1998). At the Semipalatinsk nuclear testing range in Kazakhstan, more than 500 nuclear tests were carried out by the Soviet government until popular protest put an end to the testing in 1989. Of these, 124 were carried out in the atmosphere from 1949 to 1963. Over half-a-million people were exposed to various degrees of fallout from the explosions. The local population during all these years continued to live within a few kilometers of the test site, but were offered no protective clothing, and some even watched the explosions with their naked eyes (Akiner, 1993). In short, Chernobyl was only one manifestation of a larger culture of irresponsibility that
characterized the Soviet regime’s handling of nuclear safety issues.

Origins of the Soviet Culture of Environmental Irresponsibility

This culture of irresponsibility, however, was hardly confined to the nuclear industry and to nuclear weapons. According to a report by Russia's Minister of Ecology in 1992, some 15 percent of Russia's territory is considered to be an ecological disaster zone. The areas that are contaminated also happen to be those areas in which human settlement is concentrated: the so-called fertile triangle (Large parts of the former Soviet Union are not fit for agriculture or easy human settlement due to climate). Thus, when it is said that 15 percent of Russia’s vast territory is contaminated, we are probably talking more about contamination of half or more of the prime areas for human habitation in Russia (“Health, Environment Are Deteriorating in Russia,” Current Digest of the Post-Soviet Press, vol. 44, no. 41, November 1992, p. 5).

The same report that I cited earlier by Russia’s Minister of the Environment in 1992 noted that about half of the population of Russia was drinking unhygienic water. As Feshbach and Friendly (1992) noted, bad water supply has led to high rates of bacterial dysentery, hepatitis, and cholera in much of Russia. In 1987 the USSR government acknowledged that 100 Soviet cities suffered concentrations of harmful air pollutants that exceeded government norms by at least ten times. In some areas of Kazakhstan, particularly in the north, lead concentrations in the air were 14 times the maximum permitted level, and mercury concentrations were 60 times the norm. Lead emissions in Russia are about fifty times as great as those in all of the European Union. Another report by the Russian Minister of Environment in 1997 indicated that 40 percent of the population of Russia—60 million people—today lives in cities where air pollution exceeds admissible levels (Reuters, January 23, 1997).

My purpose in going through this litany of problems is not to whitewash the serious environmental problems that face the rest of the globe, including the United States (The social movement that emerged in Kazakhstan to put an end to nuclear testing, after all, was known as “Nevada-Semipalatinsk”). But in the Soviet Union this type of patterned environmental abuse was particularly widespread. The question that has to be addressed is why? What brought about this larger culture of irresponsibility, and how is it that this behavior was so widespread, and indeed continues to a large extent in the post-Soviet period as well?

The question of where cultural practices originate is obviously a complex one. Certainly, socialization and internalization are key elements in making them self-sustaining. But so too are incentives systems. To a large degree, the onset of the Stalinist industrialization program appears to have been the key period in which a particular set of cultural habits toward the environ-
ment became institutionalized (Weiner, 1988). Certainly, we have no record of acts of this type of wide-scale environmental irresponsibility in Russia before the 1920s, although Westerners visiting Soviet plants in the decade following the Soviet takeover of power already noted the heaps of materials that seemed to be haphazardly laid out on the factory property. Although these disorganized and wasteful practices have often been blamed on the vastness of Russia and its frontier mentality assuming inexhaustible resources, more than this has to be taken into account.

The end of the 1920s and early 1930s was a crucial institutionalizing moment for Soviet culture. (It is important to note that the cultural practices of irresponsibility toward the environment that I am discussing are not only widespread among Russians, but also among non-Russians of the former Soviet Union as well). Rapid industrialization at any cost became the single-minded goal of Stalinist economic policies. Moreover, these assumptions about economic goals were translated into actual incentive systems on the factory floor—into rules and incentives that guided people’s behavior. As an expression of the focus on rapid industrialization, the Soviet industrial system set up a system of incentives that stimulated production over considerations of efficiency, quality, or environmental impact. Although the enterprise plan actually consisted of 32 different indicators, Soviet industrial enterprises tended to be judged by a single indicator of success: the so-called \textit{val}, or gross output in rubles. And because prices were fixed centrally, this essentially meant that the more that an enterprise fulfilled its production plan in terms of output, the more it earned. An enterprise could do just about anything so long as it fulfilled its \textit{val}. As Feshbach and Friendly note (1992), it was not so much the fact of planning itself as much as the yardstick that was used to measure success and allocate rewards, and the cultural attitudes that this practice embedded, that was the fatal flaw for the environment in the Soviet Union. And as I will suggest below, this was also the fatal flaw that produced the Chernobyl disaster as well.

The \textit{val} manifested itself in economic behavior in multiple ways:

1) in a single-minded focus on production without regard to other goals such as quality, productivity, cost-effectiveness, or innovation;

2) in the practice of what was known as “storming” (that is, workers loafed for three weeks of the month and gave it their all in the last week before the monthly plan target was due);

3) in the tendency to look the other way when environmental, safety, or other regulations were violated for the sake of fulfilling the plan;

4) in a culture of lying (the stakes were high, and cover-ups were ubiquitous; enterprises
lied about their resources and about whether they fulfilled the plan); and
5) in a whole series of semi-legal and illegal practices that were intended to grease the
wheels of this supply-driven economy.

These behaviors have become even more important with the collapse of the USSR, as they
formed the basis for the burgeoning of organized crime and widespread rule-breaking that have
been key features of post-Soviet reality in all of the former republics).

It is important to note that the culture of environmental irresponsibility in the former Soviet
Union was not due to the absence of rules governing environmental and safety standards. Actu-
ally, in the Soviet Union standards for pollution and workplace safety were relatively strict. A
comparison of workplace air quality standards in the U.S. and the USSR in the early 1980s
shows that in almost every case the Soviet safety standards were significantly stricter than the
analogous American standards (Pryde, 1991). Yet, in actual fact none of these requirements
were followed. When the United States adopted its first clean air legislation in 1970, its limits
on carbon monoxide were considerably more lenient than Soviet norms, which had already
been in place for a number of years before. Of course, anyone who has ever been to Russia
knows that these norms on air quality are meaningless. The real issue, though, is why these
rules in particular remained meaningless. One part of the answer is that there was no incentive
to obey them. The fines imposed for violators were minuscule—50 rubles in most instances and
100 rubles in serious cases. And more than that, there was no expectation of ever having to pay
these small amounts since polluters were very rarely fined. Essentially, factory managers had a
free hand and a strong incentive to dump wastes or to violate safety rules in pursuit of produc-
tion gains.

According to Soviet sources, the USSR produced up to twice as much pollution per unit of
industrial output as did western industrialized nations at the time (Feshbach and Friendly,
1992). In essence, the state failed in regulating itself because the state’s priorities (that is, pro-
duction over ecology or safety) were reflected in the incentive systems that it devised for gov-
erning economic behavior. But another part of the answer is that this particular set of expecta-
tions and practices became internalized so that it operated even in the absence of economic
incentives. Once this culture, supported through attendant incentives, was in place and institu-
tionalized, it became extraordinarily difficult to change, because people expected others to
behave in a certain way, and these behaviors were supported by particular industrial interests
built up through prior practice. As I have noted, the culture of environmental irresponsibility in
Russia continues to be practiced today, even in the absence of the val, largely because expecta-
tions of irresponsible environmental behavior are now well internalized.
Standard Practices and Soviet Environmental Disasters

How does this relate to the Chernobyl accident? In several ways. Probably the most important question that usually remains unasked about the Chernobyl disaster is why the safety test that led to the disaster was carried out in the first place. As Zhores Medvedev (1990) makes clear, the accident-triggering test carried out on April 25th and 26th on the turbines’ voltage regulating system was actually the completion of a series of tests that were supposed to have been passed at the time that the plant was commissioned in 1983. The reactor had been operating for two years with this known defect in its safety equipment precisely because of the rewards that the producers of the plant (Atommash) reaped for fulfilling the plan on time. Moreover, through an informal agreement, the tests were carried out not by the producers of the plant (the Ministry of Medium Machine-building), as was supposed to have been the case at the time of commissioning, but by those who were supposed to exploit the plant (the Ministry of Power and Electrification). Moreover, although representatives of the State Committee for Safety in the Atomic Power Industry, which was created only in 1983 and was in charge of ensuring safety at nuclear plants, were present at the plant, they were not even informed that this test was to take place. This was standard practice, given that safety violations at the plant had been consistently covered up over the previous years. Consider the following statement, which came from the official court verdict in the trial of the Chernobyl plant managers:

There were many unscheduled (emergency) shutdowns because of mistakes made by personnel. The causes were not always properly investigated and in some cases they were covered up. Out of 71 technical breakdowns in 1980-1986, no investigation in the causes was carried out in at all in 27 cases. Many cases of equipment failure had not been registered in the operation logs (Medvedev, 1990, 266).

The reason for the rush in completing these tests was simple: With the plant personnel practicing the customary storming, in order to fulfill their monthly plans on time Soviet enterprises were expected to be working overtime and at full capacity on April 26th and 27th because the upcoming May Day holiday meant the following three days were a vacation period. Those in charge of dispatching electricity first insisted that the test be postponed, because of the demand for electricity at the time, and then demanded that the test be carried out before the critical production days for storming commenced. The reluctance to shut down the reactor when problems were being encountered in keeping it stable also reflected the storming mentality. In short, Chernobyl was a series of structured mishaps. In some respects, the Chernobyl accident was no accident at all, but a reflection of rule-guided behaviors that reflected a repeated pattern.
of violation of safety standards.

Another example of the ways in which the Stalinist developmental model encouraged a culture of irresponsibility toward the environment was in the development of hydroelectric energy. On the one hand, hydro-energy is a renewable energy resource and can decrease other forms of energy pollution. But it also can be subject to abuses if not developed properly—which is precisely what occurred in the former USSR. Beginning in the late 1920s and early 1930s, hydroelectric dams became symbols of the country’s industrialization and of the “catch-up-and-overtake” mentality that governed Soviet development. Within a short period of time, the Soviet Union became a major producer of hydroelectric power—indeed, only second to the United States in total hydroelectric production.

One of the characteristics of Soviet hydroelectric projects is the enormous size of the reservoirs created as a result of dam construction, transforming river basins into a series of very large and shallow artificial reservoirs that flow into one another. These artificial lakes on the Volga River are so extensive that storms can produce ocean-like waves on them, eroding the soil along the shore. Soviet designers and industrialists were in such a hurry to build dams that they forgot to consider their effect on the ecological systems of the rivers on which they were constructed. For instance, because of a flaw in their design, many Soviet hydroelectric dams did not allow for oxygenation of the water, leading to the deaths of large numbers of fish populations through hypoxia. The speed with which water flows down the Volga has been reduced drastically, leading to enormous industrial waste and creating considerable health hazards for humans as well as fish (Pryde, 1991, 58-61). Due to these factors, the sturgeon population of the Caspian basin underwent a drastic decline in the 1970s and 1980s. This, combined with the enormous poaching now taking place for caviar (a market in which the Russian mafia has become heavily involved), has led to a catastrophic decrease in the sturgeon population of the region. Further down on the Volga basin, at the Caspian Sea, an increased flow of water resulting from the drainage of land upstream has also caused enormous ecological damage.

While the Aral Sea is drying up because of the overuse of the Amu-Daria and Syr-Daria rivers, the Caspian Sea is increasing in size. (Actually, the size of the Caspian has fluctuated enormously over the last century, partly because of climate change, and partly because of changes in the management of water levels upstream). In Kazakhstan twenty thousand square kilometers of land have been flooded, including hundreds of villages and more than 1400 oil wells. Waves now at times reach 20 kilometers inland from their levels in the 1970s, sanitary conditions have deteriorated, and toxic substances in the water have given rise to periodic cholera epidemics (Glantz, 1999).

Of course, these are some of the most extreme cases of environmental irresponsibility in
the Soviet Union. But the environmental abuses which occurred during the Soviet period go far beyond these disasters and translate into a much larger pattern reflected widely throughout this society. The irony is that the demise of the USSR and the collapse of post-Soviet economies has been helpful for the environment, not because the culture of environmental irresponsibility in these societies has changed, but because the economic crisis that has overtaken the region has caused the shut-down of industrial plants. As a consequence, there is now much less industrial pollution spewing into the atmosphere and rivers than in the past. However, the new governments of the region are extremely weak and do not have the ability to regulate the ecological behavior of their people, so that while Stalin’s system of incentives—the val—no longer operates, the sense of license characteristic of post-Soviet political economy functions with much the same effect. Moreover, given the drastic declines that these economies have experienced, environmental issues do not receive high priority. Most studies indicate that while some enterprises have stopped polluting altogether because they have stopped producing, pollution per operational enterprise has actually increased with the breakup of the USSR, and new environmental disasters continue to occur. Moreover, a 2002 study indicated that 60 percent of the inhabitants of Russia live in an environment harmful to their health, contributing to three hundred thousand deaths per year—more than the total of number of people who die as a result of automobile accidents (Eke, 2002).

Conclusion

To sum up, what lesson should we take away from the record of environmental devastation that accompanied communism? These were not isolated incidents, but rather very much the patterned result of a set of rules and widespread informal practices—what I have called a culture of environmental irresponsibility—that, through the unbridled pursuit of production, rode roughshod over both nature and people. This culture emerged in the 1930s, was institutionalized by a specific incentive system, and was absorbed and internalized by much of the population, so that eventually its logic was reproduced even in the absence of these incentives. The lesson provided by the very grim Soviet experience in this area is not that accidents happen or that Russians are fools, but rather that if we ourselves are to avoid our own equivalents of Chernobyl or Aral Sea disasters, we need to consider the long-term consequences of the cultural rules that we create about environmental responsibility; we have to ask whether we have indeed created the kind of culture that is supportive of the proper care of the environmental and human dimensions of production. As we have seen, it is not enough to set the rules. Rather, a culture of responsibility
emerges as a set of expectations that large numbers of people buy into. The abandoned towns and villages of Ukraine and Belarus exemplify the dangers of what happens when a society fails to create such a culture.

**Resources**


Chapter Three

THE CHERNOBYL REACTOR ACCIDENT:
WHAT HAPPENED AND WHY?

Michael L. Corradini

Maintaining public health and safety is a major requirement for the continued use of nuclear power for electrical energy production in the US as well as worldwide. For this reason it is important to have an adequate understanding of nuclear reactor safety in general and of the Chernobyl accident in particular. This chapter provides a brief description of what happened at Chernobyl in the context of the accident at Three Mile Island. Following this, I provide a quick overview of how these events have affected US policy decisions with regard to nuclear power. First, though, let me outline how a nuclear reactor functions and then discuss the accident at Chernobyl and its consequences.

What is a Nuclear Reactor?

A typical nuclear reactor consists of five main parts:

- the fuel,
- the moderator,
- the coolant,
- the control rods, and the
• radiation shield.

**Fuel**

The fuel is usually composed of either uranium or uranium in an oxide form. For current reactors this fuel is the uranium isotope, U-235, that can easily break apart (fission) when a neutron is absorbed at the proper speed. About 0.7 percent of natural uranium is composed of this U-235 isotope. The speed of the neutron has to be slow enough (that is, at speeds near room temperature, called “thermal” speeds) so that absorption by the uranium nucleus readily occurs; Note that the other isotope of uranium, U-238 (99.3 percent of natural uranium), does not easily fisson at thermal speeds. Thus, for present day reactors we sometimes concentrate, or ‘enrich’, the amount of U-235 to optimize the reactor design for the fission process in which energy is released from the transformation of mass to energy. (This energy results because the mass of the ‘fission products’ nuclei—the elements coming from the broken-up uranium atom—and the neutrons released weigh less than the mass of the neutron absorbed and the original uranium nucleus.) The fuel is normally fabricated into pellets about the size of a piece of chalk (about half an inch in diameter and an inch long) and are stacked in a metal tube (cladding) made of steel or zirconium (a metal similar to steel) with a total fuel rod length of about 12 feet. Both Chernobyl and Three Mile Island had this type of fuel rod as part of their nuclear reactor designs.

**Moderator**

The moderator is an important substance that allows the fission process to continue. Suppose that a thermal neutron is absorbed within this “chalk-size” piece of fuel so that a fission event results generating fission products. The energy produced from this nuclear reaction causes these fission products to collide with other fuel atoms and the nearby cladding atoms, thereby making all these atoms vibrate rapidly and heat the solid fuel rod. Ordinarily, the neutrons generated from the fission would fly off in all directions at very high speeds (~ 50 million mph) so that they are all too likely to escape the fuel rods before being absorbed and there is only a small chance that they would produce a subsequent fission and continue the “chain reaction”. Would. To improve the efficiency of the “chain reaction”, the neutrons must be “slowed down” and lose some of their kinetic energy (and momentum) by colliding with another substance, somewhat like a billiard ball striking another billiard ball.

These neutrons must be “moderated” by a substance that reduces their speed substantially, over 10,000-fold, in a series of these collisions. The best moderators are substances that have a
mass closest to a neutron; e.g., hydrogen atoms in water or carbon atoms in graphite. For the Chernobyl design, the moderator was solid graphite blocks surrounding a collection of fuel rods, whereas the moderator in the Three Mile Island (TMI) reactor was the water coolant that flowed in between individual fuel rods. Thus, the TMI nuclear reactor design had the inherent safety feature that a loss of coolant was necessarily also a loss of the moderator for the fission process, thus automatically stopping the fission reactor power.

Coolant

The coolant removes the heat that is produced by the fission chain reaction in the fuel rods. In some designs (the so-called boiling water reactor, BWR), the coolant is water that boils as it passes around the fuel rods. The steam then goes directly to a turbine to produce electricity as in fossil-fuel plants. The Chernobyl design was somewhat similar to a BWR in that water passed through a pressure tube bundle of fuel rods within a graphite moderator. The “reactor core” consisted of 1700 of these pressure tube bundles embedded in a 30-foot cube of graphite moderator. The actual name given to this design was RBMK, which is Russian for “pressure-tube reactor”. In other designs (the so-called pressurized water reactor, PWR), the coolant is water that is kept at high pressures to keep it from boiling. A typical pressurized-water reactor core consists of about 50,000 fuel rods in an open lattice arrangement with water flowing around each rod within a large pressure vessel. As the water is heated up it is pumped to a large heat exchanger (called a steam generator) and transfers the heat to another water loop at lower pressure. This water boils at this lower pressure and the steam is used to generate electricity as is done in fossil-fuel power plants. TMI was a PWR design.

Control Rods

In order to balance the fission rate with the cooling rate, the fission reactor is controlled by the use of rods composed of a substance (cadmium or boron in a steel or zirconium tube) that parasitically absorb neutron without producing fission. These rods are inserted into the reactor core to absorb the “excess” neutrons and maintain the fission chain reaction rate at the needed power; i.e., keep the reactor “critical”. Only one neutron has to be produced for every neutron absorbed in the fission process to achieve this “criticality” and produce the proper power level. However, the average number of neutrons released in each fission event is slightly more than one to account for the fraction of neutrons that are absorbed by the nuclear reactor structural materials, the moderator, the cooling water and finally, the control rods for reactor power con-
trol. If the number of excess neutrons rises to unreasonably high levels without being balanced by these absorption processes, then the fission chain reaction event may become “supercritical” or “prompt-critical” as the neutron population grows too fast.

In the Chernobyl plant the control rods were located in each pressure tube bundle for power control as well as to produce a shutdown. The design was unique in that it took almost twenty seconds for the control rods to be fully inserted and shut down (“scram”) the reactor. By contrast, in the Three Mile Island nuclear reactor design, the control rods were inserted at particular places in the reactor core and could be fully employed to shut down the reactor power in much less than a second.

**Radiation Shield**

The final part of the reactor is the radiation shield surrounding the reactor core region. When the reactor is in operation this shield, made of steel and concrete, protects the nearby equipment and personnel from any escaping neutrons or the radiation from the decay of the fission products. Chernobyl used steel plates around the graphite moderator encircled by concrete for shielding, whereas at TMI the steel reactor vessel, which holds the reactor core, served as this shielding together with the surrounding structural concrete.

This is all that constitutes a nuclear reactor, and it is an elegantly simple engineering device. As previously mentioned, the big difference between Chernobyl and TMI is that for TMI, the water is both the moderator and the coolant so that any loss of coolant automatically stops the fission process. This is not the case for Chernobyl; any loss of the water coolant does not remove the moderator, and the control rods still must be inserted to shut down the fission reaction. Also remember that the fission products are radioactive following the fission event and naturally decay by alpha rays (helium nucleus), beta rays (electrons) or gamma rays or X-rays (high energy photons—‘invisible light’). Thus, after the reactor is shut down by the insertion of control rods the fission products continue to decay and give off heat in this process (starting at about 1 percent of the original fission power, decreasing slowly with time), and, thus, must be continually cooled to prevent the core from overheating and eventually melting.

**What Happened at Chernobyl?**

The Chernobyl nuclear power accident occurred about 1:25 a.m. local time on Saturday morning of April 26th, 1986. This event, the most catastrophic accident in the history of commercial nuclear reactor operation, had a profound impact on the world and continues to shape global policies and practices around nuclear energy.
nuclear power, is a tragic lesson in how the lack of an inherently safe engineering design and improper testing procedures can quickly lead to a large release of radiation and subsequent adverse health effects. The accident occurred during a turbine “run-down” test. Because Chernobyl Unit #4 was scheduled for routine maintenance, electrical engineers on the plant staff planned to conduct this test as the reactor was being shut down. They had wanted to measure how much electricity would be produced after the steam stopped flowing to the turbine-generators, and the turbine “ran down” to slower speeds by its own momentum. In this Russian RBMK design this excess electricity could be employed to power the emergency pumps used to cool the reactor core with water. Only the RBMK nuclear reactors of all the other reactors in the world had such a design feature.

The engineers were scheduled to perform this test in the afternoon of April 25th, but began encountering problems in bringing the reactor down to the required power level (about 5 percent power) before the test could begin. These difficulties were partially due to the reactor operators’ inexperience with this unique design and the stress the engineers were experiencing to finish the test before reactor shutdown. To ensure that the test could be completed (or repeated if necessary), the operators did not follow their written procedures and blocked out both the emergency water-cooling for the reactor core and the automatic reactor shutdown control rods. Because of these two improper deviations from normal procedure, the reactor could not obtain additional cooling nor could it terminate the fission process during any unexpected events.

The RBMK’s unique design also had a feature that made the reactor unstable. Because the reactor fuel was moderated by graphite but cooled by boiling water, any loss of water or greater amount of water boiling caused the reactor power to increase, rather than decrease. This “positive void coefficient” made the reactor not only very difficult to control but also potentially unstable and difficult to control, particularly with respect to the test the engineers were about to perform. This is in stark contrast to the Three Mile Island reactor design, which is inherently stable and automatically decreases in power with any event that boils water. In this case, since TMI was moderated and cooled by water, like all water-cooled nuclear reactors in the United States and in the rest of the world, any loss of water-cooling or increase in water boiling would automatically shutdown the reactor fission power (and only leave the decay heat from radioactive fission products to remove).

The Chernobyl nuclear reactor power was finally stabilized at about 6 percent of full power at about 1 o’clock in the morning of April 26th. In order to achieve this stabilization the reactor operators again deviated from their written procedures by allowing the coolant flow to be set at its maximum level and removing all the adjustable control rods from the reactor core. Although
not directly a danger to reactor operation, these actions would exacerbate the unstable behavior of the ‘positive void coefficient’ noted previously and make the control of any transient event even more difficult.

At about 1:23 a.m., the operators began the test by closing the valve, which had allowed steam flow into the turbine, in order to measure the power produced during this turbine “run-down”. This valve closure caused the cooling of the nuclear reactor core to be reduced and with the reactor power being held constant (remember, reactor shutdown was blocked), more water began to boil and the reactor power began to rise rapidly because of the positive void coefficient for this unique design. This activity was inherently unstable since any power increase caused more water boiling which produced more steam and the positive void coefficient led the power to increase further. Normally, the reactor operators tried to stabilize the reactor power, but the adjustable control rods had been removed from the core and all the cooling pumps were already operating.

As a consequence, there was no extra pumping capacity available to cool the reactor core and reduce the boiling process. So, after a few seconds, the operators manually activated the reactor shutdown control rods to be inserted into the core. However, because the time for insertion was so long (about twenty seconds) compared to the reactor behavior during the transient test that was being conducted, this corrective action was too late. The reactor became ‘supercritical’ and the power rose to about 100 times normal full power in less than ten seconds. At this time, the energy produced from this overpower transient overheated the fuel rods to a point that more neutrons were absorbed in the fuel without causing fission (called a Doppler feedback). This inherent fuel characteristic allowed the reactor power to reverse itself and decrease briefly. But the fuel rods also cooled down a bit, and because very little water remained in the fuel pressure tubes, the power increase immediately began again.

This time the reactor power rose even faster, over 500 times normal full power in less than three seconds. This power transient produced a tremendous amount of energy so that the fuel rods not only overheated but also melted and partially vaporized. Although not as extreme as a nuclear bomb, the power rise was so severe that the fuel rods and the pressure tubes containing them failed structurally, and the top of the reactor was blown off by the evolved high-pressure gases, severing all 1700 coolant piping connections. The reactor operators heard all this in the control room: sounds similar to muffled explosions. Finally, because air had leaked in, the heating generated by this reactor transient ignited the graphite moderator. This is the part of the accident that was portrayed most vividly by the world’s news media. Many of us can still recall scenes of helicopters dropping material onto the burning structure and reactor operators and
firemen attempting to extinguish the fire with water hoses. It took over five days to pour enough sand and lead shot on the graphite moderator and the reactor pressure tubes so that the fire was extinguished. The heat produced by the fire was so great that although the fire had been put out, the overheated reactor core smoldered for almost five more days.

**What were the Consequences of the Chernobyl Accident?**

Following the accident on that early Saturday morning, the explosion and subsequent fire released an enormous amount of radioactivity, over 50 million curies (note that this over 50 billion times more radioactivity than is contained in a typical house smoke alarm). Over one-quarter of this radioactivity was released during the explosion, lofted into the air, and transported by weather to the northwest. In fact, it was this radioactivity release drifting over central Sweden that was detected by a nuclear power plant worker coming into work on Monday, April 28th, thereby compelling the Soviet Union to make the accident public. This catastrophic event’s most obvious immediate health effect was the death of almost thirty ‘witnesses’ of the accident—reactor operators and firemen involved in stabilizing the accident. In the intervening eighteen years, about twenty more “witness” deaths could definitely be attributed to this occurrence. To put this in perspective, the accident at Three Mile Island, while economically disruptive to General Public Utilities because of the replacement power and property costs, was insignificant in terms of the amount of radioactivity release from the containment; i.e., less than 10 curies of radioactive iodine was released from the containment—almost ten million times smaller than the Chernobyl accident. Thus, no health effects were attributed to the release of radioactivity from TMI, either right afterwards or much later.

Beyond these fairly immediate adverse health effects from the Chernobyl accident, the long-term radiation effects are not well known, but may be great because of the large number of people involved, i.e., the workers involved in stabilizing the plant after the accident, as well as the evacuees and residents outside the evacuation zone. It is estimated that the average radiation dosage various groups of people received was as follows:

- 200,000 cleanup workers received an average dose of over 30 times our normal annual natural background dosage, which is about triple what a radiation worker would normally receive in a year. 600,000 additional workers received smaller doses.

- Approximately 125,000 people were evacuated in a twenty-mile radius and were estimated to have received an average dose of about five times our natural background yearly dose.
• 270,000 people lived in the strict control zones surrounding Chernobyl and are estimated to have received about seventeen times the natural background annual dosage from 1986-1989.

• Food supplies in the Ukraine and western Russia, as well as eastern Europe, were restricted following the accident in the summer of 1986 to allow the levels of radioactive iodine to diminish to acceptable levels.

• The land area surrounding the Chernobyl reactor site (about 500 square miles) has been permanently quarantined for the foreseeable future, because the level of residual radioactivity is above natural background radiation levels.

Using the accepted international procedures for long-term health effects, one would estimate additional cancer fatalities of about 24,000 people worldwide over the next 50 years. To put this figure in perspective, consider that 600 million ‘spontaneous’ cancer fatalities would be expected over the same period of time. In contrast, there are no expected long-term health effects via induced cancer fatalities from the TMI accident. The chapter in this volume, as well as other publications, by Prof. Kelly Clifton of the Department of Human Oncology in the University of Wisconsin Medical School provides a more detailed discussion of the biomedical aspects of the accident.

**Could a Chernobyl Accident Happen Here?**

The answer to this hypothetical question is no! I can offer such a definite statement for several reasons, most notably the fundamental engineering design of the light water reactors in the rest of the world as compared to the Chernobyl RBMK design, and more specifically, the inherent safety of the light water reactor and containment design, and its associated safety systems as well as the operational safety procedures practiced worldwide. In fact, the remaining Chernobyl RBMK nuclear reactors have been substantially modified in their physical design and operational safety procedures since the accident to mimic the US design philosophy and practice. Let us review some of the key reasons in some detail.

The light water reactors in the United States use water to moderate the fission reaction as well as cool the nuclear reactor core. Thus, in contrast to the Chernobyl reactor, which has an unstable positive void coefficient (a loss of the water coolant produces a power increase), light water reactors are inherently stable (a loss of the water coolant causes the fission process to stop). Thus, the rapid power rise that occurred in the Chernobyl reactor accident is physically impossible in our light water reactors. In fact, after the accident, the Soviet designers of the
RBMK reactors were required to modify the fuel design of all of the remaining RBMK nuclear reactors to remove this instability and make them behave similar to US light water reactors.

The Chernobyl reactor was housed in a confinement building that could not constrain the large pressures caused by severe reactor accidents. In contrast, light water reactors in the United States and throughout the world are housed in containment buildings designed to withstand the very high gas pressures and temperatures (many times atmospheric pressure and temperature) produced by a severe accident. This passive boundary protects the environment from any substantial release of radioactivity. In the TMI accident, little radioactivity was released to the environment, partly due to the strong containment building surrounding the TMI reactor.

The Chernobyl accident was partly caused by the inappropriate actions of the reactor operators, i.e., removing the adjustable control rods from the reactor core, blocking out emergency reactor core cooling and automatic shutdown (scram) of the reactor fission process. None of these operator actions are possible in US light water reactors. In fact, after the accident, the Soviet designers of the RBMK reactors modified the reactor protection system so that these actions are now no longer possible in the RBMK nuclear power plants.

**Epilogue: Nuclear Power in the US at the Start of the 21st Century**

Worldwide use of nuclear power systems to generate electricity began in the 1950s with so-called generation I, prototype reactors (e.g., at Shippingport and Dresden). Generation II reactors, such as the light water reactors (LWR), which are predominantly used in the United States and elsewhere, as well as the RBMK reactors in the Soviet Union, began operation during the 1960s and 1970s. We are now in the Generation III stage, characterized by, among others, advanced LWRs; e.g., the Advanced Boiling Water Reactor being constructed and operated in Japan and Taiwan, the CE-System 80+ being built and operated in South Korea and the CANDU heavy-water moderated and now light-water cooled reactors in China, Korea and Southeast Asia. By 2030, it is estimated that Generation IV reactors will be developed and come into use. These advanced systems may be light-water reactors, gas-cooled reactors or liquid-metal cooled. But all of these systems have to be more economical and have enhanced safety systems with an environmentally sustainable profile; i.e., minimized wastes and proliferation resistance.

As I noted earlier, Chernobyl was a terrible accident stemming from a flawed reactor system design. Beyond the human tragedy of Chernobyl, however, there is the belief in some circles, strengthened by the catastrophe—particularly in the U.S.—that nuclear power is inherently unsafe and should be discontinued. Some even point to Three Mile Island as “our Cherno-
byl” even though, as I discussed earlier, the actual reasons for these accidents, and their consequences, are radically different. Despite the fact that commercial nuclear plants have not caused a single loss of life in the U.S., a good number of people think an extremely serious nuclear accident is bound to happen; the only questions seem to be when, where, and how much devastation will it bring.

This view may be so widespread to a considerable extent because much of the public has been exposed only to one side of the debate on the uses of nuclear power. The mass media might contribute to this one-sidedness. Perhaps because, in the interest of attracting the broadest possible audience, they like to feature highly dramatic occurrences, the media have generally emphasized only the possible negative consequences of this energy source. The extreme nature of a possible nuclear accident undoubtedly has a major role in shaping the public’s attitude on this issue, in subtle ways as well as, more obviously, because of the magnitude of the damage that might result. Psychological research has demonstrated that vivid, easily imagined events are often regarded as more likely to take place than are less dramatic incidents. With the idea of nuclear power now being frequently linked in people’s minds to highly dramatic images of catastrophic occurrences, many persons could well have the incorrect idea that a nuclear power plant could explode. At any rate, whatever the reasons for the one-sided presentation of nuclear power in the popular press, I have here taken only a “pro-nuclear” position in an attempt, however small, to redress the balance. The undue fears now existing about a supposedly forthcoming “nuclear catastrophe” can best be alleviated by a more accurate understanding of contemporary nuclear technology, and it is this that I have sought to provide.

However, as with any technology, nuclear power has identifiable risks that must be acknowledged, compared, and addressed. All forms of energy production are risky, partly because their by-products have potentially deleterious effects on both human health and the environment. However, the perception of risk and its severity seems to depend on the type of energy production involved. As a case in point, we are quite familiar with the by-products and risks arising from the widespread use of fossil fuels, such as visible air pollution. With fire and the burning of fossil fuels being virtually as old as humanity, their visible by-products are generally familiar, fairly well understood or accepted by most people. We are less certain about carbon dioxide and other gaseous emissions since they are not always visible or familiar and the scientific and governmental policy communities do not necessarily agree as to what are the relative costs and benefits of cutting down on these particular by-products.

Renewable energy sources are appealing. Wind, solar, and geothermal fuel sources are ‘free and natural’; they are familiar, understandable, and visible. (But even so, their cost, variability or uneven availability and real impact of actually making these technologies usable on a
societal scale is often ignored.) Nuclear power is very different by comparison. It utilizes a discovery, fission, which is relatively recent and is not understood by many laypeople. It also produces something invisible, called “radiation”. Radiation can cure or cause cancer, or sterilize our products or change our genes. Moreover, it is associated with weapons of mass destruction. The result is that with nuclear power, more than other technologies, answers are wanted for a number of questions such as:

- How is nuclear energy used to make electricity?
- What is a nuclear reactor and how does it operate?
- What are the issues that could affect its future use?

And in this last regard, we often hear:

- What are the effects of radiation on health?
- Are nuclear power plants safe enough?
- How can we handle nuclear waste?
- What are other environmental effects?

These are important questions and answers should be forthcoming. However, it is curious that, more than all other technologies, the common expectation for this particular technology, whether it is rational or not, is to have essentially “zero-risk.”

Beyond the technologies and their comparative values and drawbacks are the less tangible but perhaps even more important questions regarding energy use and its costs of production. It is clear that the per capita U.S. consumption of energy greatly exceeds that in any other country and this energy usage is increasing. It is also clear that, at some point, the growth rate of this energy consumption must be reduced and ways of generating energy must be identified that do not place a heavy impact on environmental or human health and that also lessen the United States’ geopolitical vulnerabilities stemming from its excessive reliance on energy imports.

To help frame the debate, we must consider several factors. The following list of matters to be kept in mind, coming from an analysis carried out by the Wisconsin Institute of Nuclear Systems, is not intended to be an exhaustive specification of relevant considerations, and certainly is not intended to stack the deck in favor of nuclear power but can serve as a foundation for our examination of the desirability of this energy source.
What is the Current and Projected Energy Use in the U.S.?

Data from 1999 provide a useful start: Seventy three percent of the energy used in this country at the end of the twentieth century came from domestic production, with the remaining 27 percent being imported. The domestic production had the following sources:

- Fossil (58 percent, oil, gas, coal)
- Nuclear (8 percent)
- Renewables (7 percent, predominantly hydroelectric)

If we look at the purposes to which the energy was put, one third of the energy was used to generate electricity. Two thirds of the electricity-generating energy, in turn, came from fossil fuels, almost a quarter from nuclear power, and the remainder from hydroelectric, geothermal, etc.

Now consider the rise in energy consumption. The overall growth rate of energy use is over 1.5 percent per year, which is roughly the average worldwide population growth rate. However, the worldwide growth rate of electricity use is over three percent per year, an increase in the rate of consumption that is twice as fast as the overall population growth. If this increased rate of usage is met by the current production means, roughly two-thirds must be provided by fossil fuels. Both the environmental concerns and the geopolitical issues stemming from unequal access to such fuels to meet this demand must be part of a rational energy policy.

What are Some of the Energy Production Issues?

Any truly rational assessment of the desirability of nuclear power generation should also be based on a comparison of this power source with other technologies on a variety of matters, such as the extent to which they have a negative environmental impact. This match-up is favorable for nuclear power in several respects. For example, look at the area taken by a power plant per thousand megawatts of energy produced (assuming the plants are running at 100 percent capacity). Where plants consuming biomass fuels and plants employing wind-driven turbines both require more than 100 square miles of land for this power generation, solar-photovoltaic plants need more than 40 square miles, and coal-burning plants at this power level use between 7 to 14 square miles of land. By contrast, nuclear plants typically take up far less land—only...
3.5 square miles.

Then, too, what about the amount of by-products emitted by a power plant per 1000 megawatts per year of power generated? The following table shows the approximate amount, in metric tons, emitted as such by-products by coal, gas, and nuclear power plants in 1999:

<table>
<thead>
<tr>
<th></th>
<th>Coal</th>
<th>Gas</th>
<th>Nuclear</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulphur oxides</td>
<td>1000</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Nitrogen oxides</td>
<td>5000</td>
<td>400</td>
<td>0</td>
</tr>
<tr>
<td>Particulates</td>
<td>1400</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ash</td>
<td>1 million</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>7 million</td>
<td>3.5 million</td>
<td>0</td>
</tr>
<tr>
<td>Spent fuel</td>
<td></td>
<td></td>
<td>35</td>
</tr>
<tr>
<td>Fission products</td>
<td></td>
<td></td>
<td>Less than 1</td>
</tr>
</tbody>
</table>

Adding to these figures, the next table reports the percentage of all the energy generated by the various technologies in 1999 that was emission-free:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Nuclear</td>
<td>69.2 percent</td>
</tr>
<tr>
<td>Hydroelectric</td>
<td>29.1 percent</td>
</tr>
<tr>
<td>Geothermal</td>
<td>1.3 percent</td>
</tr>
<tr>
<td>Wind</td>
<td>0.34 percent</td>
</tr>
<tr>
<td>Photovoltaic</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Here we clearly see some of the advantages of nuclear power: It requires the least area to produce a given amount of electrical energy, and in generating this energy spews out none of the pollutants that give rise to health problems and global warming. On the negative side, it is of course the only technology that produces left-over spent fuel that is radioactive.

These figures obviously have no bearing on the issues of plant safety, the conveyance and storage of radioactive byproducts, and the chances that weapons-grade fissionable materials can get into the hands of those whose intentions are not in the best interest of the world-wide community, and these issues clearly also have to be considered. The policy debates over the storage of spent fuel are not easily resolved because of fears about “leakage” and opposition to the use...
of certain geological sites for this purpose. Much of the opposition to the proposals made stem, of course, from a “not-in-my-backyard” point of view rather than from the assessment of scientific data. However, a somewhat reassuring comment can be offered here on the matter of plant safety. Not a few laypeople believe that nuclear power plants “emit radioactivity” and therefore pollute the waters and soils. In actuality, though, these plants typically release to the general public only approximately one-tenth of the background radiation produced by other human-made sources. I might also note, in regard to the possible theft of fissionable material, that the United States adopted a non-recycling nuclear power fuel cycle in the 1970s in order to reduce this threat, although this policy also results in a far less efficient use of fuels. Needless to say, this is a political issue and will require a political solution.

A Final Comment

Nuclear power in its present form is not the ideal energy source and may be eventually be supplanted by other, better technologies. But for the foreseeable future, it is economical, safe, and environmentally friendly compared to others. It is not the only technology that we should use, but it should be one that is evaluated on its merits rather than on a largely unwarranted extrapolation from disasters such as Chernobyl. This assessment can be carried out in the United States by means of public discourse and debate, with protections against abuse provided by our form of government. Such a discourse and open debate cannot occur, however, without an educated and informed public willing to do its part.
Chapter Four

THE SEMANTICS OF “INHERENT SAFETY” (1)

Arjun Makhijani and Scott Saleska

The general arguments of advanced reactor advocates, some of which may be conceptually plausible and appealing, are difficult to either verify or refute in the abstract. This is because they are all essentially in the design stage, with only very limited details made public. Although greater incorporation of passive safety features, if undertaken with care and rigor, could be an advance in reactor design philosophy, we are concerned with the constant references by advanced reactor advocates to the supposed “inherent safety” of their designs.

Regardless of the validity of claims about immunity to the meltdown accident scenario, this terminology of “inherent safety” has more rhetorical merit than technical content. It is fundamentally mis-leading to describe as “inherently safe” a technology which necessarily contains and produces such large amounts of extremely hazardous material as does nuclear power. Although it may be possible to design a reactor which renders certain accident scenarios virtually impossible—or to make reactors that are considerably safer relative to existing reactors—that does not mean that the technology per se can be considered to have acquired safety as an inherent characteristic.

As stated in a 1990 study by the Union of Concerned Scientists (UCS), which considered several advanced reactor designs:
As a general proposition, there is nothing “inherently” safe about a nuclear reactor. Regardless of the attention to design, construction, operation, and management of nuclear reactors, there is always something that could be done (or not done) to render the reactor dangerous. The degree to which this is true varies from design to design, but we believe that our general conclusion is correct. (2)

This conclusion is not limited to groups such as the Union of Concerned Scientists, which maintain a healthy skepticism about nuclear power. A study conducted by Oak Ridge National Laboratory also has reached similar conclusions:

A nuclear reactor can never be completely inherently safe because it contains large quantities of radioactive materials to generate usable heat-energy; but nuclear reactors can be made inherently safe against some types of events and have characteristics which limit consequences of certain postulated accidents. (3)

These cautionary statements raise another crucial concern: the possibility that in designing to eliminate certain now commonly recognized accident possibilities, new accident scenarios will be unwittingly introduced. As a survey of advanced designs by Britain's Atomic Energy Agency concluded:

Safety arguments, in many cases, are very underdeveloped, making it difficult to gauge if the reactor is any safer than traditional systems. [Advanced reactor] designers tend to concentrate . . . on one particular aspect such as a [loss-of-coolant accident], and replace all the systems for dealing with that with passive ones. In so doing, they ignore other known transients or transients possibly novel to their design. (4)

This is an important warning. Nuclear technology is complex, and it has taken many years of analysis and experience to even recognize the existence or the possibility of some accident possibilities for the four-decade-old light water reactor. The history of nuclear power development is replete with instances of incidents occurring at operating power plants which had not previously been thought possible. This is even true of the meltdown scenario, which was not even recognized as a safety issue until the mid-1960s—over a decade after the decision to build the Shippingport reactor. In view of this history and the complexity of reactors, it would be prudent to anticipate that similar unexpected discoveries may be encountered in the development of a new generation of reactors based on any new design.

The verification of the safety claims of any particular vendor, of course, requires that the details of the design be made public so they can be examined for potential safety flaws. Handwaving arguments about general design features which are alleged to guarantee inherent safety should not be allowed to substitute for actual design details and real-world data on actual com-
ponents. To a large extent, however, the fine engineering details do not yet exist for designs that are not yet “construction ready.”

The entire debate to date on the issue of the level of safety of new reactor designs has taken place largely on a theoretical level. While theoretical work is a necessary part of design, it cannot settle all essential safety questions by itself. Even the degree of relative safety of a reactor design is no easy matter to determine. Questions relating to the net level of improved safety are highly complex, and rely on substantial analysis of the fine details of design and experience accrued over time.

Safety uncertainties can never be fully resolved in advance, and will inevitably remain large until many years of operating experience have been acquired with advanced reactor designs. That is a crucial problem in the development of nuclear power. Operating experience is needed to make the right decisions about overall designs as well as critical detail, but getting that operating experience in itself involves non-negligible risks, at least if the scale of reactors is anywhere close to those required for large-scale commercial power generation. The only approach that could resolve this aspect of the problem of nuclear power is to study designs on paper thoroughly and then to acquire long experience with small scale devices, much in the manner that small-scale models of airplanes are tested extensively in wind tunnels prior to construction of full-scale prototypes.

**Accidents and Nuclear Technology**

Three major reactor design concepts have been put forward since the start of the nuclear era that have been implemented in commercial nuclear power:

- water-moderated and water-cooled reactors (light or heavy water);
- graphite-moderated (water-cooled or gas-cooled);
- unmoderated liquid sodium-cooled fast neutron reactors.

As with any technology, there have been a variety of problems in the development and implementation of nuclear power plants which have led to improved safety features. Some malfunctions were the result of experiments to test reactor designs, as was the case with the partial meltdown of the EBR I reactor in Idaho.

Despite the considerable progress in understanding reactor safety over five decades (including experience with Manhattan Project reactors), the potential for catastrophic accidents
continues to exist. A major reason is that nuclear power reactor designs were selected too quickly on the basis of energy, economic, military, and political criteria that did not give sufficient weight to the problems associated with catastrophic accident possibilities.

Light water reactors, by far the most common design today, were the simplest for the U.S. to build in the short term and hence gave the largest propaganda advantage to the United States during the Cold War. But this meant that the laboratory and theoretical work that was needed to understand the most severe accident, the loss of coolant from the reactor core, was completed over a decade after the 1954 decision to build Shippingport. By that time, the investment in the light water reactor was so great that the main reaction of the AEC was to try to cover up or downplay the seriousness of the problems.

There are at least three questions pertaining to catastrophic nuclear power plant accidents that are germane to the evaluation of the soundness of nuclear technology as a choice for future energy supply:

- Is it possible to learn enough from non-catastrophic accidents in small-scale plants to prevent future catastrophic accidents in large-scale ones?
- Is the scale of the accident such that the ill-effects could far exceed the benefits of any economies to be gained from nuclear energy versus some other energy choice?
- Which generations would pay the price for the accident consequences—that which got the energy benefits or future generations?

Similar questions can also be asked about other technologies. [Here] let us examine the Chernobyl accident, by far the worst in the history of nuclear power, for the lessons it might have to offer.

Chernobyl

On April 25, 1986, the operators of the Chernobyl Unit Number 4 were scheduled to perform an experiment designed to test an aspect of the safety of the RBMK design. The experiment was delayed for a number of reasons, including difficulty in stabilizing reactor power level. The operators decided to proceed with the test at 1:22 a.m. on the morning of April 26. Thirty seconds after the test began, an automatic computer printout indicated unsafe conditions, requiring the reactor to be shut down immediately.

There followed a runaway supercriticality, which greatly increased the power level, heated up the reactor, and increased the steam pressure in it to such high levels that it exploded, blew off the top of the reactor, and destroyed it. Less than 90 seconds had elapsed between the com-
puter warning to shut the reactor and the total destruction of the reactor.

Thirty fires were ignited in the reactor core and in other parts of the power plant, including the turbine building. Firefighters arrived at the scene an hour-and-a-half later. They extinguished fires other than those in the reactor core relatively rapidly, but the reactor graphite fire lasted for ten days. Radioactivity releases went on for months after the fire had been extinguished. (5)

It was one of the two worst industrial disasters in human history, the other being the December 1984 disaster at the Union Carbide plant in Bhopal, India, during which deadly methyl isocyanate gas was released. In both accidents, hundreds of thousands of people were affected during the accident and in its aftermath. Thousands died on the night of the Bhopal catastrophe; in the case of Chernobyl, the immediate toll has officially been reported as 31, which is on the order of a hundred times lower. But the affected population increased dramatically in the aftermath of Chernobyl—130,000 people were evacuated, including the entire population of 45,000 in the town of Pripyat. More were evacuated subsequently, and hundreds of thousands of workers and soldiers were pressed into entombing the leaking reactor, digging up and burying vast quantities of highly contaminated soil, and performing other clean-up jobs.

Official estimates put the cumulative release of radioactivity between April 26 and May 6, when the fire was put out, at about 80 million curies. Of this total, 45 million curies are attributed to xenon-133, 7.3 million to iodine-131, 1 million to cesium-137, half-a-million to cesium-134, and 220,000 to strontium-90. (6)

These official Soviet estimates are misleading and understate the actual extent of the releases. For instance, the release estimates are adjusted for decay to ten days after the accident began. Xenon-133 has a half-life of 5.27 days and most of it was emitted early on in the fire. On this basis, the actual amount in the fallout cloud as it passed over communities was considerably greater. Similarly, iodine-131 has a half-life of 8.05 days and far more of it was deposited on grazing lands than indicated by the decay-corrected estimate of 7.3 million curies.

Zhores Medvedev, the Soviet scientist who first reported on the other nuclear catastrophe in the Soviet Union, the explosion in a high-level waste tank at Chelyabinsk-65 in 1957 (7) states in his study of the Chernobyl accident that the official figures for radioactivity releases include only the amounts deposited inside the former Soviet Union and do not take into account the much larger deposition of some radionuclides, such as iodine-131 and cesium isotopes outside Soviet territory. According to his analysis, this is because the Soviet government did not want to acknowledge “any liability for radioactive contamination of the environment in other countries” and hence it insisted that “the amount [deposited outside the Soviet Union] was negligible.” Medvedev estimates that releases of radioiodine and radiocesium were about three times
higher than the official estimates cited above. (8)

One of the most important, unanticipated features of the Chernobyl accident was the ten-day duration of the fire, accompanied by a correspondingly long time during which large releases of radioactivity continued. As Medvedev points out, the modeling of nuclear power plant accidents generally assumes a single, short-term release of radioactivity. Weather conditions during such short releases can reasonably be assumed to be constant. As a result, severe accidents are assumed to have a fallout trace that forms a single elongated, cigar-shaped pattern, much like the typical fallout pattern from a nuclear bomb explosion near ground level. This assumption is sometimes valid. It was, for instance, the pattern of radioactivity released as a result of the 1957 Soviet explosion in a tank containing highly radioactive waste. But it was not valid for the Chernobyl accident.

During the ten days of the fire, which was accompanied by huge releases of radioactivity, wind directions and the weather changed many times. As a result, large, widely scattered areas in many compass directions were affected. Rainfall in some areas during this prolonged period created hot spots of radioactivity in three states of the Soviet Union, now separate countries: Ukraine, Belarus, and Russia. Countries far beyond the Soviet Union were also affected. Europe was especially affected by the fallout, and levels of iodine-131 in milk exceeded officially permissible levels in many countries. Every country in the northern hemisphere received some fallout from the accident.

An “exclusion zone” 30 kilometers in radius was established and, after delays, 130,000 people were evacuated. Agriculture and commercial activities were also prohibited in the area. But the actual area that was contaminated and the number of people affected was far larger. There were hot spots as much as 100 to 300 kilometers from the accident that had radiation levels on the order of one thousand times above natural background. Long-lived biologically sensitive radionuclides, notably cesium-137 and strontium-90, were deposited in large quantities. Figure 8 shows a map of contamination around Chernobyl.

Iodine-131 concentrates in milk. When this milk is consumed, it concentrates in the thyroid glands, especially affecting children. After the iodine-131 decayed away in a few months (ten to 20 half-lives), milk produced in the contaminated regions continued to be affected by cesium-134 and cesium-137 contamination. The ill effects of cesium-137 will last for a hundred years or more. There was a ban on open-market milk sales in several regions, affecting 20 to 25 million people for more than a year after the accident. (9) Even with these extensive measures, milk production was not halted in all contaminated regions. Some people in the most rural areas immediately around the plant consumed contaminated milk in the aftermath of the accident at a time
when sales of such milk had been banned in Kiev. Cesium-137 contamination of milk will continue for many decades.

The region around Chernobyl consists largely of swamps and soggy forest land. Much of the land has been reclaimed for agricultural use, the dominant use at the time of the accident being cattle grazing. The prevalent ecological conditions are conducive to retention of cesium and to its rapid transfer to plants. As a result, agriculture was affected over a vast region. The most immediately affected area was the 30-kilometer radius exclusion zone in which 70,000 hectares (175,000 acres) of fields, grazing land, and vegetable and fruit gardens were abandoned. In June, there was a further evacuation of 113 villages outside the exclusion zone in Belarus and Ukraine. Between 100,000 and 150,000 hectares (250,000 to 375,000 acres) of agricultural land were abandoned.

Levels of cesium-134 and cesium-137 contamination are especially important as criteria for suitability for agricultural use. Medvedev estimates that “if international standards were being applied for the use of agricultural land, nearly one million hectares would be considered lost for a century, and about two million hectares would be lost for ten to twenty years.” (10) There have been anecdotal reports of large increases in farm animals born with genetic defects. At one collective farm, 27 abnormal calves were born in the year after the accident, while none had been reported in the five years preceding it. The number of suckling pigs with genetic defects increased from three cases in five years to 64 in one year. (11)

Most contaminated agricultural land continues to be used for farming. Indeed, many people who were evacuated from severely contaminated areas have returned to them due to economic problems in the areas to which they were relocated and the wish of many older people to live and die at home.

A large amount of agricultural produce in Europe had to be dumped due to contamination from fallout. For instance, most vegetables in the region around Munich were destroyed because they had become contaminated with iodine-131. The southern portion of the former West Germany was more contaminated than the rest of it. There were also severe restrictions on agricultural activities, including sales of meat from three million sheep and lambs in northwestern England and the neighboring portions of Scotland and northern Wales, which were affected by rain-out of radioactivity when the fallout cloud passed over them.

**Health Effects**

Several categories of people have been and will be affected adversely by radiation doses from the Chernobyl accident:
Workers in several categories: those who were in the plant, put out the fire, cleaned up afterwards, built the concrete structure around the burned-out, exploded reactor, and monitored or otherwise performed supporting functions in contaminated areas.

- The people in the region whose land and homes became contaminated.
- People in the regions who consumed, continue to consume, or will consume contaminated food and/or water.
- People who received radiation doses from the fallout, with the highest doses generally being in the former Soviet Union and Europe.

The assessments of adverse health effects from the accident have varied widely. Official reports have tended to concentrate on the 31 workers who died of severe radiation exposure. But this position ignores the far greater numbers of people who were exposed to considerable levels of radiation, became ill in the months and years that followed the accident, and who have an elevated risk of various radiogenic diseases in the years to come. It also does not take into account the effects of the accident for decades to come.

One complicating factor in assessing the health risks due to the accident has been the severe deterioration, bordering in many areas on collapse of social services, including health delivery services in the former Soviet Union. As a result, the increases in diseases and death due to radiation exposure are mixed up with those arising from the general deterioration in medical care and economic conditions.

Some indication of the potential health damage can be obtained by looking at the radiation doses. The range of exposures of the people who lived in the exclusion zone was generally of the same order of magnitude as the survivors of Hiroshima and Nagasaki—that is, about one rem to several tens of rems external gamma radiation. In addition people were exposed to beta radiation and internal doses from various radionuclides, such as iodine-131 and cesium-137. The officially estimated cumulative population dose for the 135,000 people who were initially evacuated (with delays) is estimated at 1.6 million person-rem. Applying a risk factor of 0.0004 cancers per person-rem to this dose yields an estimate of 640 fatal cancers.

Medvedev has pointed out that the official dose estimate includes only external radiation. It does not include doses from consuming contaminated food, such as milk continuing cesium isotopes and iodine-131. It is now clear that internal exposures are a significant factor in long-term effects of the accident. Thyroid diseases, including thyroid cancer in children generally attributed to the consumption of milk contaminated with iodine-131, have registered huge increases in the fallout areas. Ten- to one-hundred-fold increases in thyroid cancer among children in the
affected region have been reported. (12) Over the decade, tens of millions of people will have been put at significantly increased risk, and it is reasonable to assume that many will die as a result. The poor state of both medical monitoring, as well as curative medicine in the former Soviet Union, means that medical systems are not likely to record many of these deaths as having been related to the Chernobyl accident. But that cannot negate the documented magnitude of the immense contamination and risk to which the present and future generations living in tens of thousands of square kilometers of highly-contaminated land are being, and will continue to be, exposed.

The number of deaths from increased exposures even in the far-off contaminated regions in the European Community (EC) are projected to be large. The British National Radiation Protection Board estimate that up to 1,000 additional cancer deaths will occur in the EC region due to radiation doses from radiocesium and iodine-131. Medvedev considers this a “minimal assessment.” (13)

Medvedev has cited the entire range of estimates for cancer deal estimates that have been made. The lowest estimates are 200 to 6 additional cancer deaths in the former Soviet Union, while the higher estimate is 280,000 additional cancer fatalities worldwide.

These estimates do not include adverse health effects on work and soldiers who were the clean-up crews and hence among the most severely affected. There are no systematic records of their exposure, or even of how many of them were involved. Medvedev quotes an eye-witness account of the working conditions of the soldiers who did clean-up work in the immediate aftermath of the accident:

I saw soldiers and officers picking up graphite [ejected from the reactor core by the explosion] with their hands . . . There was graphite lying around everywhere, even behind the fence next to our car. I opened the door and pushed the radiometer almost onto a graphite block. Two thousands of roentgens an hour . . . Having filled their buckets, the soldiers seemed to walk very slowly to the metal containers where they poured out the contents, You poor dears, I thought, what an awful harvest you are gathering... The faces of the soldiers and officers were dark brown: nuclear tan. (14)

Medvedev estimates that the radiation tan on the soldiers' faces indicates skin doses of 400 to 500 rem, that many of them suffered from acute exposures, and that some died as a result. No records have been kept or made public, at any rate, of the numbers of soldiers involved in such activities or of their exposures.

Large numbers of workers were also exposed to high levels radiation in the years that followed when a concrete “sarcophagus” was built around the burned-out reactor building to try to
encase the radii activity. Two hundred thousand men, working very short shifts, were involved in its construction. The radiation levels were extremely dangerous, with the most radioactive areas measuring between 5,000 and 20,000 rads per hour. The sarcophagus was built in the hope that it would contain the radioactivity for an extended period. But it has already deteriorated considerably and new measures to contain the radioactivity appear to be necessary. There is no consensus on the appropriate approach to contain the enormous amount of radioactivity in and under the building, but whatever measures are taken, they will be costly. If measures are not taken, the costs, in terms of contamination of important sources of water supply of the region, could be far higher.

The overall costs of the Chernobyl accident are so vast and extend over so many generations that they are impossible to calculate. The official calculation of eight to 11 billion rubles (1988), or roughly ten to 15 billion dollars. But any evaluation is complicated by the fact that a large number of clean-up workers are neither being followed or treated. It is also very difficult to quantify the economic and social losses caused by the uprooting of hundreds of thousands of people. Further, the high radiation doses received by many mean that problems other than cancer are also likely to occur. For instance, diseases induced by the weakening of immune systems of clean-up workers and off-site populations who received high radiation doses could cause large health and economic impacts. But, given the state of the health delivery systems, they would be difficult or impossible to detect.

Finally, the negative impact of Chernobyl on the electricity systems of the former Soviet Union is still being felt and enormous costs loom in terms of preventing the spread of radioactivity from the reactor, pre-venting accidents at other reactors of the same design, and replacing reactors generally considered to be unsafe well before their design lifetimes. The costs of replacing electric-generating capacity not provided by RBMK reactors, which are generally considered to be far too dangerous in the West, could by itself run into tens of billions of dollars.

Some Lessons of the Chernobyl Disaster

The most important and tragic lesson of the Chernobyl accident is the most severe kind of nuclear power accident can actually happen. Nuclear power technology is unforgiving. It has often been stated by proponents and opponents alike that it does not allow room for mistakes. Design, management, and operator errors have typically combined to yield accidents; in many cases, these same features have also helped limit the damage. In the case of Chernobyl, the factors propelling the situation toward a major accident completely overwhelmed any checks in the system.
It is generally agreed that accidents on the scale of Chernobyl or worse are more probable in the former Soviet Union and Eastern Europe, but they are also possible elsewhere. That potential has been demonstrated events such as the 1979 Three Mile Island accident and the British Windscale reactor fire in 1957. The scale and the irremediable nature of the damage from Chernobyl leads to a crucial question: Is it possible to design nuclear reactors that would not be subject to accidents of such catastrophic magnitude? This is not the same as ruling out all accidents, which is clearly impossible with any technology. It is merely to ask whether the damage can be limited so that it is at least remediable in its worst aspects.

As we have discussed, current nuclear power plant designs do not meet this goal. LWRs, graphite-moderated reactors, or sodium-cooled reactors in the West all have vulnerabilities in design and/or operation that could lead to severe accidents. The record shows that the probabilities of catastrophic accidents are lower in the West than in the former Soviet Union. But this is an inadequate response, given the nature of the consequences and the fact that energy alternatives that would avoid catastrophic accident potential are available.

We can grant that the safety of nuclear power plants in the United States has improved over the decades, as public vigilance and the Three Mile Island accident have forced the manufacturers to conform to stricter safety standards. However, these efforts cannot negate the fact that current power reactor designs are vulnerable to catastrophic accidents. Chernobyl demonstrates that the effects of such accidents are as devastating as they are irremediable. In this context, it is well to recall a criticism of nuclear power plant safety efforts made by Nobel laureate physicist Hannes Alfven in 1972:

The reactor constructors claim that they have devoted more effort to safety problems than any other technologists have. This is true. From the beginning they have paid much attention to safety and they have been remarkably clever in devising safety precautions. This is . . . not relevant. If a problem is too difficult to solve, one cannot claim that it is solved by pointing to all the efforts made to solve it. (15)

Endnotes


4. As reported in Nucleonics Week, 1989, p. 9.


9. Ibid., p. 111.

10. Ibid, p 110.


Chapter Five

THE POLITICAL CONSEQUENCES OF THE CHERNOBYL DISASTER IN BELARUS AND UKRAINE

David R. Marples

The Soviet civilian nuclear power industry was founded in 1954 when Soviet factories manufactured RBMK (graphite-moderated) reactors that had been converted from the military program. The industry faced many problems. It did not develop on a large scale until the 1960s and, especially, the 1970s. The civilian program had gotten started in a period of general prosperity with an oil and gas boom, and it initially seemed that the new atomic power stations would be required mainly in areas with a sparse population. Even the coal industry enjoyed some success in this early Brezhnev period. However, with the onset of economic stagnation, oil and gas became important sources of hard currency so that more of these resources were diverted for export. The authorities sought, as a replacement, an energy supplier that could provide for the bulk of Soviet consumers who lived in the European part of the country, avoid the typical Soviet transportation and delivery problems, and while serving local needs, still have enough energy left over for export. Nuclear power appeared to be an answer to this optimistic ambition.

Ukraine was the focal point of this program, partly because of its large population and industrial base (coal, steel, chemicals), and partly because of its water systems having a number of large rivers and reservoirs that could support the construction of an atomic plant. From the
outset there was strong opposition locally to the building plans, particularly the nuclear plant at Chernobyl, Ukraine’s first and the only one making use of RBMK reactors. Strong critiques of the way in which the plants were being built in Ukraine can be found on the pages of the newspaper Literaturna Ukraina (Marples, 1987, Chap.4). (1) The newspaper’s columns depicted all the defects and problems that are now familiar reading to those acquainted with Soviet nuclear energy: construction defects, shortage of parts, lack of training of operators and other personnel. These reports have now been verified and expanded in a series of documents released from the archives of the Ukrainian KGB. (2) Although Ukraine’s other plants were all to be based on VVER (water-water pressurized) reactors, the program was bewilderingly extensive. It included new stations at Rivne and Khmelnitky in the west; at Mykolaiv and Kerch (Crimea) in the south; Zaporizhzhya in the centre-south; and Chyhyryn, which was on the Dnipro, Ukraine’s main river. In the major cities the goal was to construct nuclear-fired heating plants close to the city centres, with Odesa, Kharkiv, and Kyiv to have the first three such stations according to the plans.

The Chernobyl (Chornobyl in Ukrainian) station was founded in 1970, and located in a remote region of the Polissyan Marsh, on the Uzh-Pripyat river system, which links up with the Kyiv Reservoir, the main supply of drinking water for the Ukrainian capital city. It took its name from a medieval town of the same name, some 15 kilometres south. The Dnipro River extends from that reservoir down to the Black Sea. The city of Kyiv, which in 1986 had a population of 2.4 million, is located 137 kilometers to the south of the station. Three kilometres to the north was the town of Pripyat, with 45,000 people, built for the plant workers and their families. Elsewhere the settlements were (and remain) mainly rural: farms in which resided predominantly elderly people, often of mixed Ukrainian-Belarusian-Russian stock. The Chernobyl station, named after V.I. Lenin, is 15 kilometers south of the Ukrainian-Belarusian border and about 90 kilometers west of Bryansk Oblast in Russia. The Soviet planners envisaged a huge facility that would, in its first stage, comprise three sets of twin reactors, each reactor being 1,000 megawatts in capacity. Pripyat was anticipated to grow to a population of 200,000 residents, so that at the time of the accident, it was less than a quarter of its expected peak size. Unit one came on line in October 1977, and others followed in 1979 and 1981, with Unit Four becoming operative in 1983. By 1986, Unit Five was 85 percent completed and Unit Six 15 percent completed.
The Accident

The story of the accident in the early morning of April 26, 1986 has been told many times. (3) The official reaction was delayed for forty hours and muted. The public heard from Radio Moscow that an accident had occurred, with two personnel having been killed, and that a government commission had been appointed to investigate the situation. The accident occurred during a safety test to monitor power generated during a shutdown. The operators working at the time were electrical rather than nuclear engineers and not trained for an experiment of this nature. The local residents in Pripyat and the village of Chernobyl saw the sky light up and many described a shudder, but the following morning none took precautions as a result of the accident and there were even two weddings in the city.

About eight hours before the official Soviet announcement, Swedish officials had discovered high radiation levels on the shoes of workers at one of their own nuclear plants and realized that the source of this radiation was somewhere in the northwest of the Soviet Union. The Soviet government then felt it had no choice but to acknowledge the disaster. At first, the authorities in Ukraine ordered the evacuation of all residents within a 10-km radius of the reactor, but on May 2nd, when two Politburo officials arrived from Moscow—Evgenii Ligachev and Nikolay Ryzhkov—this area was extended to 30 kilometers. These distances were clearly very arbitrary because initially no one knew the extent of the area that had been contaminated.

The reactor continued to spew out radioactive isotopes until May 10th, at which point the gaping hole in the roof of the fourth reactor had been filled by a combination of sand, boron, and lead pellets. The radiation first blew northward, directly over the territory of Belarus. When the wind changed direction on the fourth day, the radiation spread southward over the city of Kyiv. Ukrainian party leaders were quick to remove their children and grandchildren from the capital city, even though preparations were under way for the annual May Day celebration. For a brief time there was panic at rail and bus stations in Kyiv, although the authorities continued to insist that there was no danger. An enormous clean-up campaign began that, according to various sources, made use of over 600,000 people. At first the authorities recruited volunteers, but subsequently they used military reservists, many of whom were ordered to Chernobyl for 30 days but who stayed well beyond that time period. Likewise, the official maximum full body count of radiation (the BER or REM) was supposed to be 25 per person, but this limit was also ignored in practice. Many people worked without Geiger counters.

Information on health problems was under the control of the Academy of Medical Sciences of the USSR. Before long, such information was classified and it became very difficult to obtain.
accurate data about the health effects. Even the official number of victims was a state secret. The reported toll never rose beyond 31 (28 of whom were declared to have died of radiation sickness) even when it was manifest to most observers that the actual number of casualties was far higher. The only detailed information concerned the firemen and first-aid workers who had fought the graphite fire and had died or were hospitalized afterward. Information about reservists was in the hands of the USSR Ministry of Defence, which generally refused to acknowledge that radiation was the cause when they subsequently fell ill and died. All these factors were important in the eventual political repercussions of the Chernobyl disaster. The government was widely regarded as unduly deceitful and secretive. Officials, such as the Ukrainian health minister, Anatolii Romanenko, went out of their way to calm the public, assuring them that the health situation was safe and that it was permissible even to swim in the rivers.

Meanwhile, the General Secretary of the CC CPSU, Mikhail Gorbachev, took 18 days to respond publicly—far longer, for example, than the much maligned Vladimir Putin after the accident on the Kursk nuclear submarine—and then used the disaster for a propaganda exercise on Soviet television.

In August 1986, the Soviet account of the causes of the accident, related at a meeting of the International Atomic Energy Agency (IAEA) in Vienna, Austria, appeared to be a breakthrough in the official campaign to create a more open and frank Soviet society. Valerii Legasov, deputy director of the Kurchatov Institute of Atomic Energy, led the Soviet delegation. He basically blamed the accident on human error rather than the inherent defects within the RBMK reactor (defects spelled out by Corradini above in Chapter 3). The Soviet team attributed the disaster to an extraordinary combination of circumstances, including the deliberate dismantling of safety mechanisms that would have shut down the reactor. However, many observers were beginning to point out the fundamental problems with the Chernobyl plant: that its roof was made of combustible material; that the authorities had prepared adequately for an accident from above the reactor, but not below. The reactor actually sank into the ground and contaminated the ground water, partly as a consequence of the material dropped onto the roof by helicopters to prevent the further exit of radioactive materials.

Legasov had the reputation of being a “whiz-kid” at the Kurchatov Institute, which had made him somewhat unpopular in various quarters. At Vienna he had concealed some deeply-felt misgivings, particularly about the flaws in the reactor complex at Chernobyl. Two years after the accident, on April 27th, 1988, he committed suicide, and his memoirs, some of which appeared posthumously in Pravda, revealed a man utterly disillusioned with the Soviet nuclear industry and its refusal to address its own problems. His death raised many questions, not least
the obvious one: how much was known about these questions by the CC CPSU Politburo? According to Gorbachev’s memoirs the answer is “not much.”

The former deputy to the USSR Supreme Soviet, Alla Yaroshinskaya, on the other hand, regards Chernobyl as a massive cover-up operation, citing as evidence the minutes of the Politburo meetings of the time, when the gravity of the situation seemed to be evident to all members of the Politburo, from Gorbachev downward (Yaroshinskaya, 1995). (4) However, understanding the gravity of an event is not necessarily akin to knowing the full details and Gorbachev was no scientist.

The overall scale of the accident—it may legitimately be called an industrial disaster—is evident from a Ukrainian source. The affected population of the former Soviet Union numbered about 23-24 million people. Of this figure, and in the most contaminated regions, 100,000 were evacuated from their homes immediately after the accident; 300,000 lived in the zone of obligatory evacuation until 1992; 4.5 million dwelt on territory having an increased level of radiation in the soil; and about 600,000 were clean-up workers. In Ukraine, 700,000 lived in the zone of “voluntary” migration and over 1,000 people resided illegally in 16 irradiated population points, i.e., towns and villages (Institute of Sociology, 1996, 17). (5) Even more seriously, in Belarus, the republic most affected by high-level radiation fallout, 12 percent of all population settlements were contaminated by the accident at Chernobyl. Of these, 80 percent were located in Gomel’ Oblast (Homel in Belarusian), in which 60 villages out of its total of 100 were afflicted. One third of all peasant settlements in Mogilev (Mahileu) oblast suffered a similar fate. Together, these two regions suffered over 85 percent of the high-level radioactive fallout. The third region to be affected was Brest Oblast to the south-west, which had 166 contaminated population points. (6) Emphasis on the most acutely contaminated regions should not belie the fact that 80 percent of the republic was exposed to a fallout of radioactive iodine nuclides in the first days after the explosion.

The Political Consequences (Phase One)

There was some speculation, especially among western analysts of the USSR, that there would be major repercussions from the Chernobyl disaster. The senior Ukrainian party boss, Volodymyr Shcherbytsky, appeared to them a likely victim, along with the First Secretary of Kyiv Oblast (in which the Chernobyl plant is located), Hryhorii Revenko. But they remained in office and only minor party officials suffered dismissal, i.e., those in Pripyat and areas of Chernobyl Rayon, many of whom had fled the scene as soon as they learned of the accident. (7) Outside
the party, three officials at the Chernobyl plant were dismissed on May 12, 1986. In 1987, the
director of the station, Viktor Bryukhanov, the chief operator, and four other officials were
made to stand trial in the town of Chernobyl. Aside from the first and last days of this trial,
when local and foreign journalists were permitted to attend, all the proceedings were held in
secret. A bitter Bryukhanov, who was not present at the time of the explosion, received ten
years of hard labour; the others got from two to five years. (8) They were the main political
victims in the immediate aftermath of the accident. The Minister of Medium Machine Building
(the atomic weapons program) was also removed from office, a sure sign that the station was
originally linked to this program. However, as he was 88 years old, this was hardly a major
event. For some thirty months, the party hierarchy of Ukraine, as well as those in Belarus,
remained in place despite the enormity of the event.

Gradually, however, there was a public reaction to the secrecy surrounding Chernobyl. On
November 13, 1988, the normally conservative confines of Kyiv were shocked by a mass dem-
onstration in which some 10,000 took part, the largest ever in Ukraine. (9) The authorities had
permitted a meeting that supposedly would focus on ecological issues, but the gathering testi-
fied to the link between ecological and political questions. The Green World ecological associa-
tion had formed in December 1987, although it was not yet formally registered. The speakers at
the meeting included well-known literary figures, members of the Ukrainian Helsinki Union,
and also persons belonging to the Popular Fronts from Latvia and Lithuania. They attacked
grandiose industrial projects and presented resolutions demanding not only that construction be
halted on the nuclear plants at Chyhyryn and Crimea, but also that the remaining three reactors
at Chernobyl (all of which were by now back in service) be closed down.

In Belarus, the effects of the disaster were more traumatic, although for some time the full
extent of the radiation fallout was unknown. In October 1988, a Belarusian Popular Front
formed, partly as a result of public anger about the secrecy surrounding Chernobyl and its im-
 pact in Belarus, and partly as the offspring of a movement to commemorate the victims of Sta-
lin in the republic from the 1930s. (10) It was a movement for a national revival led by an ar-
dent Catholic from the Hrodna region, Zyanon Paznyak. Despite the fact that Belarus was po-
litically even more tied to the Soviet system than Ukraine, and the level of national conscious-
ness was lower, Chernobyl was one of the issues that served to alienate part of the population
from the Soviet leadership in Moscow. However, the authorities at first descended on the Popu-
lar Front with venom, equating it with wartime collaboration with the Germans, refusing it
access to the official press, and forcing it to hold its founding congress outside the republic, in
Vilnius, Lithuania. Only in the spring of 1989 could one discern any significant political reperc-
ussions in Belarus that were a direct result of the Chernobyl catastrophe.
The Revelations of Spring 1989

In the spring of 1989, the Moscow press released information that provided a more complete picture of the extent of the radioactive fallout from Chernobyl. Maps showed that radiation had spread well beyond the 30-km zone. Ukraine had contaminated spots in about ten percent of its territory, including regions as far west as the Polish border. In Belarus, about one-fifth of the country was designated as contaminated, an area having a population of approximately 1.9 to 2.2 million people (depending on the source one used). These figures of contaminated areas, moreover, were based only on the fallout of radioactive cesium, strontium, and plutonium (particularly the former), which served as the criteria for evacuation (over 15 curies per square kilometre of cesium-137 in the soil). The effects of radioactive iodine, noted above and also discussed in Clifton’s chapter in this book, were disregarded. The maps of Belarus indicated severe contamination in Homel, Mahileu, and Brest oblasts, and part of the western Minsk oblast. The press’ revelation incensed the population and inculcated a general mistrust of official reports. New evacuations took place, with up to 500,000 people ultimately being moved or permitted to move (not all of them were willing to leave their homes).

In Minsk on April 26, 1989, what had been an annual march to commemorate the disaster became a mass protest permeated by a new anger at official deception. One of its leaders was Gennadii Grushevoy, founder of a new NGO, the Belarusian charitable fund “For the Children of Chernobyl,” who was arrested afterward but subsequently released. A year later, a notable rise in thyroid gland cancers among children was observed in Belarus, where the rate of this illness had been almost negligible prior to the accident. In fact, virtually all the cases had occurred in the contaminated regions of Homel and Brest, among children who were born or conceived prior to Chernobyl but who were under five years of age at the time of the catastrophe. Plans to build a nuclear power and heating station not far from Minsk were quietly abandoned.

Scientists noted that 60 percent of the high-level fallout from Chernobyl had descended on Belarusian territory. The republic belatedly acquired the victim status that hitherto had been limited to Ukraine. Two years later, with the dissolution of the Soviet Union, both republics had to bear the financial costs of the disaster by themselves, although neither was in a position to meet such an obligation.

Who is to Blame? Political Consequences (Phase Two)

The focus after the spring of 1989 turned to the perpetrators of the calamity. First of all, the Soviet planners and ministries were targeted. Clearly all the decisions about the location and
operation of nuclear power stations had been made by people outside the confines of the two republics—Belarus and Ukraine—which had suffered the most. Thus from the outset there was a regional aspect to the protests: They became attacks on the centre (Moscow) and on centralized power over industry and energy. But ministries are impersonal in nature, made up of faceless bureaucrats, and it would have been easy to fault only the relevant organizations as a whole. However, for some of those investigating the responsibility for the disaster, it was simply not enough to blame the ministries. They wanted the names of individuals, those who had deceived and lied to the people. Yurii Shcherbak, leader of the Green World (and subsequently Ukraine’s ambassador to Israel, the United States, and Canada) demanded that criminal proceedings be instituted against the guilty parties. There was a decided difference on this matter between the scientific elite, on the one hand, and journalists, environmentalists, and literary figures on the other. The IAEA, which had organized an investigation into the health effects of Chernobyl in 1990, and published the results in the spring of 1991 (IAEA, 1991), was involved in this rift. Its report maintained that there had not been any serious discernible health consequences that could be definitively linked to Chernobyl. To the population in the affected areas, this report broadened the concept of “enemy” from the Soviet officials to the nuclear community generally. The IAEA was soon regarded as part of the pattern of official deception.

Shcherbak, meanwhile, cited three main “villains”: first of all, Boris Shcherbyna, the first chairman of the USSR government commission established to deal with the effects of Chernobyl (he died shortly afterward); Yurii Izrael, the chairman of the USSR State Committee for Hydrometeorology and Environmental Control; and Leonid Ilyin, the Vice President of the USSR Academy of Medical Sciences. (11) All three, in his view, had misled the general public about the real health effects and dangers deriving from the enhanced levels of radiation. However, the ultimate villain was Gorbachev as the General Secretary (and later the President of the USSR. Whoever bore the responsibility, the republics gradually moved from environmental to political protests. Chernobyl was the first of several events that alienated the union republics from Moscow and led ultimately to the dissolution of the Soviet Union.

Was this protest campaign justified, worthwhile? Must there always be a scapegoat for a disaster of such magnitude? Yaroshinskaya and others thought so but this attitude—at least to a western observer—possesses in spirit something of the Soviet mentality. In the post-Soviet period, and particularly in Belarus, the political consequences of Chernobyl have become much more complex. No one could seriously claim that the leadership of the Communist Party of Belarus, then under Nikolay Slyun’kov, was responsible for the disaster and its consequences. Indeed Slyun’kov tried gainfully to assist the victims and was frequently seen in the affected
regions. At worst, one could say that the BSSR leadership lacked courage to make decisions, such as to evacuate the endangered people without obtaining the prior permission of the Moscow bosses. It was a symptom of the fallibility, the helplessness of the old system when faced with a catastrophe of such enormity.

Eventually, however, Chernobyl became a broader issue than villains and victims. It turned into a cause embraced by the opposition; it became equated with subversion, a desire to change the leadership of the independent state that emerged after the end of the Gorbachev regime. According to official propaganda, those involved in such campaigns were exaggerating the dangers of the accident’s-produced radiation and causing panic in the southern and south-eastern regions of the republic. Let us examine briefly this complex phenomenon.

Chernobyl and Independent Belarus

The Chernobyl problem in Belarus had several aspects, including officially administered evacuations, supplying clean food and water to contaminated regions, re-cultivating the irradiated land, and above all providing aid to the various victims (which might be in the form of housing or health care or funds for evacuation). At one stage, Chernobyl-related matters accounted for 22 percent of the annual budget of the country, an amount that few governments could afford, least of all an impoverished republic struggling to deal with severance from the USSR, as well as internal conflicts. Throughout the 1990s, the government had to deal with the fact that whatever the health consequences of the accident—and they were significant—the most serious problem derived from the psychological impact of Chernobyl on perhaps a majority of people in the republic. The catastrophe has affected the national psyche in a way that is scarcely imaginable in a Western country. In a republic that has no tradition of self-initiative, and whose people are customarily reliant on state aid, state advice, and state control generally, many feel bereft today, believing that there is little chance their situation can improve. The health picture in Belarus has declined in virtually every sector of the society. Demographically, the population continues to fall as the birth rate is exceeded significantly by the rate of mortality, and the general level of morbidity is far higher in 2003 than it was in 1993. (12)

Under these circumstances, Chernobyl has been a rallying word for the opposition. The accident is the one issue that can still draw a massive crowd to a demonstration full of bitterness and anger. And at the same time, it is one event that the Lukashenka administration, which has been in power since July 1994, would like to forget or even deny, because of the use made of this disaster by the opposition, identified with the Belarusian Popular Front or the Christian
Conservative Party of the BPF. A 1993 survey indicated that the population had little confidence in the ability of state organizations to help them alleviate problems engendered by the accident. (13)

In his “cover-up” Lukashenka has insisted that the contaminated lands be re-tilled, that the militia should serve in these areas, and that the number of official victims be reduced to the minimum. A majority of victims has already been removed from the official “invalids” list, and most of the NGOs formed to assist Chernobyl victims have been persecuted either in subtle ways—such as being audited by the KGB—or by open harassment. Outsiders dealing with Chernobyl victims are today usually obliged to work through the authorities in Minsk. Chernobyl has thus come under centralized control just as in the Soviet period.

This situation can be contrasted with that in Ukraine, which economically was also in severe difficulties in the first decade of independence. In Ukraine there was the added predicament of the Chernobyl plant itself coupled with international pressure since 1994—when the IAEA finally declared that the station was unsafe—to shut it down permanently. While Ukraine closed the station down by the end of 2000, the concrete shell over the destroyed reactor has to be replaced. International aid, particularly from the United States, France, and Germany, was urgently required for this and other programs. Partly in consequence, the government of Leonid Kuchma has concentrated much of its efforts on remedying the severe impact of the accident on society, particularly on the health of the victims. Indeed, the Ukrainian health minister and the Ukrainian Chernobyl Union have claimed there are tens of thousands of deaths from Chernobyl, claims that are not accepted by a cynical outside world inclined to believe that Ukraine is using the accident as a way of obtaining more external assistance. Whatever the reality of the health picture in Ukraine, there is no dissension on this matter between the government on the one hand and its opposition on the other. The adverse effects of the Chernobyl disaster are just as pervasive today as they were eighteen years ago. It remains a human tragedy that continues to affect large areas of the country.

By contrast, in Belarus, Chernobyl is fated to be associated with the opposition, a loose term that denotes the variety of political parties (many of whom have now formed a United Opposition under OSCE auspices) that seek to end Lukashenka’s rule. (Among the reasons for this antagonism to Lukashenka were the fact that he had extended his term of office by a dubious referendum in November 1996, as well as affecting subsequent manipulations of the 1994 Constitution.) With this linkage between Chernobyl and its opponents, the government does not permit further extensive inquiries into the overall consequences of the catastrophe. In 1996, when the Children of Chernobyl Charitable Fund held its third international congress entitled “The World After Chernobyl,” the authorities first cut off the microphones, then blocked some
controversial speakers from entering the conference hall, and finally evicted the delegates altogether, forcing them to move to a German joint venture hotel on the outskirts of the city. (14) This pressure was not a result of the nature of the speeches and discussions that were about to take place. Chernobyl was a dangerous issue only because of its association with enemies of the government. Like the Stalinist massacre of prisoners at Kurapaty just outside Minsk, it was an issue that the authorities wished to see put to rest, forgotten. It is ipso facto a political issue, and for the Lukashenka government, can be dealt with as such away from the glare of the world media that have focused on Ukraine, the locale of the notorious nuclear power station.

Conclusions

The situation in Belarus is more extreme than elsewhere, but many of the pressure groups that were formed after Chernobyl have now also died out in other republics. Chernobyl sparked an extensive movement against nuclear power that almost ended the programs in Russia, Lithuania, Armenia, and Ukraine. But with independence, the perceived root cause of the problem—the Moscow centre—disappeared, leaving a void in its place. In countries such as Lithuania, nuclear power became the mainstay of the energy program of the independent republic. In Ukraine as well, nuclear energy makes up about 45 percent of all electricity production. Not surprisingly then, the political consequences of the accident reached their peak in the period from 1989 to 1991: from the time when an extensive area of contamination was acknowledged by Moscow to the collapse of the Soviet Union in December 1991. The mass protests in Ukraine and Lithuania then ended with this collapse. In Armenia, the nuclear power station was also returned to service after independence because the energy-starved population in a virtual war zone could not do without this energy source.

In Ukraine today, the Chernobyl question has taken second place to acute political tensions and in-fighting between the government and the parliamentary opposition. Chernobyl and the problems that it has caused served at various times as a convenient excuse for the Ukrainians to justify slow progress in a number of areas, such as economic reform and the privatization of agriculture. One ostensible reason for the delay in closing the station was the fate of the population of Slavutych, the new city in Chernihiv Oblast that was constructed from late 1986 onward to house the former residents of Pripyat. Ukraine was reluctant to abandon the city and thereby raise the level of unemployment further. Its nuclear industry leaders complained frequently that undo attention is being focused on Ukraine and the RBMK reactors at Chernobyl, whereas relatively little is being said about the other reactors of the same type that continue to operate.
in Russia (Sosnovyi Bor, Kursk, Smolensk) and Lithuania (Ignalina). In their view, these reactors are considerably more dangerous because they have not been subject to the sort of technical improvements made at Chernobyl. Nonetheless, as noted, Chernobyl in 2004 was no longer a key media issue.

In Belarus, the situation is fundamentally different. Ironically, the onset of the Lukashenka administration may owe something to the accident. The president won the 1994 election, at least in part because of his role on a commission to investigate corruption in the republic. In short, the public saw him as outside the post-Soviet hierarchy, as untainted by the various scandals and failures that had pervaded the government over the previous three years, including Chernobyl. For the present government the Chernobyl accident appears to be less a tragedy in the history of Belarus rivalling that of the German-Soviet war than a form of criticism used by the opposition to undermine the Lukashenka administration. The demonstrations on April 26th remain the largest annual protests in Minsk, bringing out far more people than the commemoration of the anniversary of short-lived Belarusian National Republic of 1918, for example, or the April 2nd protests against the Russia-Belarus Union dating from 1996. Chernobyl has become a political issue rather than a medical or social one. Ironically, Belarus faces more danger from the Ignalina nuclear plant on its northern border than it does from the now defunct Chernobyl station.

Lastly, one should ask whether the reported effects of Chernobyl in Belarus have been exaggerated. Is the present Lukashenka administration justified in wanting to “end” Chernobyl as an issue of debate? The answer to the first question is an undeniable “yes,” in that virtually every medical problem in the affected regions, and even in Belarus itself, has at some time been attributed to the disaster. The serious drop in the living standards in Belarus has clearly been of greater significance in bringing about the plethora of medical problems highlighted by the doctors’ congress that took place in 1998 (Marpl es, 2000, 16-27). (15) A pervasive Chernobyl “myth” is today as significant in its social and political impact on the population as the myth of the partisans in the Second World War, or—to go back earlier in the century—the Bolshevik Revolution of 1917. In this myth, Chernobyl is not so much an accident but a crime of international dimensions perpetrated by the scientific community led by the IAEA, an organization that has as its main goal the promotion of nuclear power. In the words of Yaroshinskaya, it is “Lie 86: A lie as global as the accident itself” (Permanent People’s Tribunal, 1996, 3) The culpable party is thus less definable than the Soviet state under Mikhail Gorbachev, which in any case no longer exists. That the IAEA has been blinkered and narrow at times in its approach seems irrefutable, but this certainly does not mean that the organization is involved in an international plot to conceal a crime of horrific magnitude from an unsuspecting world.
On the other hand, Chernobyl is clearly one factor in this country’s general malaise and bears the chief responsibility for the epidemic of thyroid gland cancer among children. Many of its health effects remain unknown, particularly when it is impossible to determine precisely the cause of a disease. Land remains severely contaminated, especially in Homel region, and the rural population lives off this land, consuming irradiated products. And Chernobyl for Belarusians is clearly the main event of the later Soviet period, the one denoting an historical era: before and after Chernobyl. The emotional paintings by Belarusian artists are emulated by schoolchildren, providing clear evidence of the way in which the accident has affected their consciousness. Chernobyl continues to have a profound influence on the population of Belarus and Ukraine, one that is unlikely to recede in the coming years, whether that impact is based largely on reality or on fantasy. This influence will persist, moreover, even though the official media, guided by their respective governments, would prefer to ignore the effects of this two decades-old disaster.

Selected References

(This listing shows only those works cited in the chapter that are in English.)


Endnotes

(With some occasional exceptions, these notes refer to sources cited in the chapter that are not readily available in English.)

1. I have documented many of these critiques in Chapter 4 of my book, Chernobyl & Nuclear Power in the USSR.

2. See, for example, “Dopovidna zapyska KDB URSR do TsK KPU pro systematychni porushennya tekhnolohii provadzhennya budivel’no-montazhnykh robiv na okremnykh dilyankakh budivnytstva Chornobyl’s’koj AES, 17 sichnya 1979r.” (Report note of the KGB of the Ukrainian SSR to the Central Committee of the Communist Party of Ukraine about systematic violations of technology in the conducting of construction-assembly work on certain sections of the construction of the Chornobyl atomic power station, 17 January 1979).

3. One of the most detailed accounts of these early days after the accident emanates from Ukraine: Vitaliy Fedorovich Sklyarov, Zavtra byl Chernobyl’: dokumental’naya povest’ (Kyiv, 1991).

4. The Russian version of Yaroshinskaya’s book, published in Moscow in 1992 as Chernobyl’: sovershennno sekretno, contains over 300 pages of official documents pertaining to Chernobyl and illustrating the various deceptions carried out by Soviet leadership, especially regarding real radiation levels in the contaminated regions. For example, one Protocol, issued on 6 May 1986 by the Operative Group of the CC CPSU Politburo cited information from one of its members, Deputy Chairman of the USSR Ministry of Health. O.P. Shchepin, that at 9am on 6 May, 3,454 people had been hospitalized as a result of Chernobyl. Of this number, 367 had radiation sickness, including 19 children, and 34 of this number were in a critical state. A rise in the level of radioactive contamination had been observed in the rivers Pripyat and Teterev: Chernobyl’: sovershennko sekretno, pp. 272-273.


7. Despite being politically a natural opponent of Gorbachev’s policy of Perestroika, Shcherbytsky remained in office until his retirement in September 1989, at the age of 71. He was retired with full honors. On the 85th anniversary of his birth in 2003, there were several discussions in the Ukrainian media concerning his legacy. See, for example, http://www.day.kiev.ua/DIGEST/2002/24/1-page/1p2.htm

8. Rabochaya gazeta, 1 August 1987.


11. See, for example, Radyans’ka Ukraina, 20 February 1990.

12. The mortality rate has exceeded the birth rate in Belarus for the past ten years. In 1993, the population was
10.24 million; in 2003, it had fallen to 9.84 million. See, for example, http://www.president.gov.by/Minstat/ru/indicators/population.htm


14. The author was present at this Congress.

15. For a detailed account of this Congress and its results, see Marples, 2000, 16-27.
Chapter Six

HOW THE STATE AND SOCIETY RESPONDED TO THE NEEDS OF THE UKRAINIAN VICTIMS OF CHERNOBYL:
A VIEW FROM UKRAINE (1)

Volodymyr Tykhyy (2)

Volodymyr Tykhyy worked as a physicist in areas contaminated by the Chernobyl nuclear explosion from 1987 to 1989, after which he became an active board member of the Ukrainian Environmental Association, and then a project manager and director of the Greenpeace Ukraine Office. He is now at the Environmental Education and Information Center in Kiev.

At the time of the Chernobyl catastrophe Ukraine was the second largest republic of the fifteen in the Union of Soviet Socialist Republics (USSR, or Soviet Union), having a population of 51 million to Russia’s (the largest republic) 144 million in 1986. The Soviet Union was a strongly-centralized state, with one very powerful ruling organization, the Communist Party of the Soviet Union (CPSU), dominating all of the USSR’s components—governments, local authorities, army, businesses, cultural groups, and indeed, the society as a whole. Formally, the republics were self-governed, but in reality, all important decisions were taken in Moscow by the Central Committee of the CPSU and the so-called Union Government. The highly vertical management system was one of “command and control,” with its backbone being the Communist Party committees at all levels—central, republic, oblast, and district. There were also party committees at enterprises, organizations, villages, and city quarters, which controlled the implementation of decisions made at higher levels. All resources, including financial—for industries, housing, food, and so on—were distributed by the central government in Moscow.
Given this system, the local governments and industries were to function as lobbying groups for their regions and enterprises in Moscow. Realistically, though, state policy could only be influenced by raising an issue of concern at the meetings of the low level party committees, seeking to have the issue then proceed upward in the hierarchy. But of course, only ideas supported by high-level party authorities had some chance of being implemented.

In 1985, a new and dynamic leader of the CPSU, Mikhail Gorbachev, launched perestroika, the reconstruction of the whole Soviet system, which led to a substantial weakening of the Communist Party’s authority. One important feature of perestroika was glasnost, the policy aiming at permitting the free and open expression of one’s opinions and allowing the publication of information once suppressed. The facts regarding the Chernobyl disaster and its consequences could now be disclosed, and matters relevant to this calamity became public policy issues. Glasnost also enabled active political forces in the republics, starting in the Baltic region but soon followed by groups in Ukraine, Belarus, and elsewhere, to begin a struggle for their independence.

These were not separate developments. Recognizing that protests against nuclear power plants and polluting industries could be seen as politically neutral or even patriotic, the independence movements often initially employed relatively safe “green” slogans favoring ecologically-sound policies in advancing their programs. They also argued that the secrecy with which the Soviet government had enshrouded the Chernobyl catastrophe and its aftereffects, the horrific nature of these consequences, and the absence of real consultations with the sufferers, all demonstrated the necessity of real changes in the state system.

Pressure for change also came from the extremely severe economic problems facing the Soviet Union in the 1980s because of the huge expenses of the long-lasting Afghanistan war, the armament race with the United States, and the dramatic drop in world crude oil prices in 1985. (Oil was one of the USSR’s main export commodities and the chief source of hard currency income.) The Chernobyl disaster, along with other unfortunate occurrences, also contributed to the economic difficulties. Extremely massive investments of money, labor, and material were required to mitigate the dire consequences of the calamity. Radiation victims and the evacuees from areas contaminated by fallout required urgent help—and their problems added to the financial and material difficulties arising from the need to aid other groups, such as the casualties of the Afghanistan war, the victims of the military conflicts in Azerbaijan, the refugees from Georgia, the sufferers of the Spitak earthquake in Armenia, and the population in the area of Aral Sea.

In August 1991, after the unsuccessful attempt at a coup d’état in Moscow, the Ukrainian
*Verkhovna Rada* (Parliament) proclaimed the Act of Sovereignty of Ukraine. The Communist Party lost its all-dominating role, and in less than a year, the USSR disintegrated. Ukraine was now an independent state with full responsibility for all matters, positive and negative, of concern to the nation as a whole, including the legacy of the Chernobyl catastrophe.

From the first, the governments of independent Ukraine faced enormous problems in coping with, much less eliminating (often called “liquidating”), the terrible consequences of the nuclear calamity. These problems were exacerbated by the enormous inflation in the years 1992 to 1995 and the general breakdown of the national economy caused by various factors. The rapidly decreasing quality of life throughout the country in those years did not allow the undertaking of many of the measures deemed advisable to ameliorate the living conditions of those directly affected by the accident and to protect those threatened by its aftereffects. It is hard to judge whether there was even an adequate political will to resolve many of the difficulties.

**“Liquidating” the Consequences of the Disaster**

In keeping with the USSR’s highly centralized control structures, the logistical problems arising from the necessity of coping with the consequences of the devastating accident were first dealt with at the highest governmental level, in Moscow. The “command-and-control system” was still strong at this time and for several years afterward. Indeed, it could be said that the Soviet Union operated more or less as an army. Workers for the jobs carried out were recruited from all fifteen republics, with a large proportion coming from Ukraine. Some were volunteers, since the financial compensation offered for the possible health problems was quite high, but many were young conscripts and soldiers who carried out their assignments dressed in military uniform.

**What Happened**

The first statement about the Chernobyl catastrophe from the USSR Council of Ministers acknowledged that “an accident has taken place at the Chernobyl power station, and one of the reactors was damaged.” It then went on to say: “Measures are being taken to eliminate the consequences of the accident.”
The Liquidators

Those who started taking these “measures” are the first big category of sufferers to be discussed here, the "liquidators.” No one knows precisely how many of these persons there were. A common estimate puts the numbers at around 600,000, and of these, according to recent data, about 180,000 former liquidators live in Ukraine. These people have been properly lauded as heroes because of their courage and commitment to their responsibilities. It should also be remembered that they lacked adequate equipment and did not even have the right kind of clothing or respirators to protect themselves from radiation or even dosimeters to measure the radiation levels around them. Medvedev (1990, p. 43) reported that by the end of the first ten days “almost all of the local firemen” had been sent to Moscow’s radiological hospital, and that a good many men “suffered later from acute radiation sickness.” Those who had fought the fire in the immediate area of Reactor No. 4 all died, according to Medvedev.

Thousands of other specialists and workers were soon involved in a variety of urgent measures undertaken to contain and then “liquidate” the effects of the disaster. To cite one notable example of these activities, miners from Donetsk Oblast were brought in to dig a tunnel under the damaged reactor in an effort to cool and strengthen the basement of the reactor building. Hundreds of them are now suffering from various diseases. Equally dramatic, for six days, helicopters were used to dump five thousand tons of lead, boron, and sand on the heart of the burning reactor in order to dampen the fire and contain the radioactivity. Many of the helicopters and their pilots were contaminated by the radiation to which they were exposed. Today, almost two decades later, one can still see giant helicopters lying discarded in a field within the exclusion zone, too “hot” to be used in any way. Needless to say, the pilots, and the others working with them, were also grievously affected.

In the next phase of the liquidation operation, from May to November 1986, a giant sarcophagus was erected over the highly radioactive ruins of Reactor 4. Even though the radiation levels were very high in that immediate area, tens of thousands of construction workers, engineers, and drivers were drafted to work on this project, and used more than 400,000 cubic meters of concrete and 7,000 tons of steel to create the containment. While all this was going on, a deadly decision was made to restart Reactor No. 3, which was situated on the same basement as the ruined No. 4 and was controlled by many of the same communications. Thousands of workers, who constructed the necessary walls and rearranged the thousands of pipelines and electric circuits required to operate the third reactor, were also subjected to substantial amounts of radiation.
Yet other tasks were carried out, also exposing the personnel to doses of radiation, sometimes relatively high and others less severe. In the years after the accident, efforts were made to decontaminate the buildings, roads, and equipment, and again this involved hundreds of people, including vehicle drivers, dosimetrists who assessed radiation levels, and those who washed the irradiated structures and machines. In the course of this decontamination, houses in tens of villages were demolished and buried, and the so-called "red forest" adjacent to the power plant (an area hundreds of hectares in size) was cut and buried in specially dug huge ditches. (3)

The people providing the needed food, housing, and transportation for those doing all this work were also affected, to some degree at least, by radiation. Tens of thousands of persons resided in the city of Chernobyl, 30 km from the nuclear power plant, during this period. The biggest canteen in Chernobyl, established in a huge ward originally built to service vehicles, could house more than 1000 men at a time. And of course, the Army and militia (police) regiments guarding the fence around the 30-km exclusion zone also were also irradiated, to some degree at least. Whatever the level of radiation they encountered in their work, most of them had only the simplest basic understanding of what might be happening to them.

The Area’s Residents

The second very large category of victims (and we’re here speaking only of those in Ukraine) consists of the residents of the areas contaminated by substantial radioactive fallout. Generally speaking, the region experiencing the highest level was that within a 30-kilometer ring (18 miles) around the nuclear power plant—the so-called “exclusion zone.” Although the Soviet government was at first reluctant to move many of these persons, for economic rather than health reasons according to Medvedev (1990, p. 96), organized evacuations soon got underway (also see Marples, 1988). Perhaps not surprisingly, party officials were the first to be moved, along with workers who operated the power plant. The residents of Pripyat, where most of these workers lived, were evacuated two days after the accident. (Told at the start that they would be gone for only three days, they never returned to their homes.)

The resettlement process continued at some level for several years, in part because, with time, the authorities lowered the radiation level deemed unsafe for habitation. And so, in 1989 the people residing in a much wider area than the original 30-km exclusion zone were taken from their homes (Marples, 1996a). Like so many other aspects of the catastrophe’s aftermath, here too pertinent data are ambiguous and often inconsistent, and it is unclear exactly how
many people were resettled as time went by. (4) Even with these evacuations, in 1990 about 1.5 million people lived on contaminated land in Ukraine.

Other chapters in this publication, especially those by Moore, Clifton, and Patrick, summarize many of the studies delving into the biological consequences of radiation, and this matter will not be gone into here. It is worth noting, however, that people residing in areas exposed to considerable fallout were told not to eat wild berries and mushrooms, although these particular foods, traditionally called “gifts of the woods,” are a very important part of their diet, and they also were discouraged from using the milk of their cows and goats. (5) With all of these restraints, externally and internally imposed, the traditional economy of the region’s collective farms producing milk, meat, potatoes, linen, and so on, collapsed.

It is hard to say whether the evacuated people (except for a limited number of nuclear power plant personnel and other privileged persons who received comfortable apartments in Kiev and other big cities) were generally better off than those who remained in contaminated areas. Speckhard’s chapter discusses some of the stresses and strains experienced by a good number of the evacuees, such as their lack of jobs, the stress of having to develop new lifestyles and social routines, and their sense of being alienated from the others around them. Although some of these persons found shelter with their relatives and friends all over Ukraine, many were moved to newly constructed villages where they lived, more or less, like refugees.

The new settlements, built under a great time pressure to house those to be resettled, were often of very poor quality and occasionally even had inadequate sewage removal. Other people were moved to established communities, but even there, were often regarded as unwelcome, perhaps even dangerous, strangers. Marples (1996a) told of a family taken from a contaminated zone in Belarus that was resettled in a presumably “clean” area in Ukraine. “At their new destination they were shunned by their neighbors who feared the newcomers would contaminate them.” Their children were also ostracized at school for this reason. “The situation became so intolerable,” Marples reported, “that the family decided to return” to their contaminated home. Quite a few other evacuees met the same unfriendly reaction.

I will have much more to say about these evacuations later in this chapter.

The Role of the News Media

The Soviet Government’s policy regarding what information could be released about the Chernobyl accident was formulated in a simple order of June 27, 1986: “To consider as secrets: data about the accident; data about results of treatment of sufferers; data on irradiation of personnel
involved in liquidation of the consequences of disaster.” The numerous illnesses afflicting the liquidators and the population of contaminated areas were to be attributed to “radiophobia.”

It was perestroika and glasnost that eventually led to the disclosure of the truth about the accident. As was already mentioned, democratic movements emerged in many republics of the USSR, and many of them, emphasizing ecologically-friendly policies, were decidedly “green” in their orientation. In Ukraine, the first unofficial big rally (i.e., that was not initiated by an order from the party committee) was organized by the Ukrainian environmental association, Green World, in Kyiv in November, 1988. At this gathering, participants accused the official medical authorities of hiding the number of Chernobyl victims, the dangers of living in contaminated areas, and the lack of adequate care for liquidators and evacuated people.

Movie documentaries provided a good deal of information about the accident’s aftermath. One of the most successful of these was the documentary filmed by Georgi Shklyarevsky (Microphone!), which revealed the truth about radiation levels in the Narodichi district of Zhytomyr Oblast. Other documentaries and journalistic articles soon followed. Rolan Sergiyenko’s documentaries (Threshold, Bells of Chernobyl, and others) had an important role in disclosing the liquidators' sufferings. Still, the authorities attempted to block the exhibition of some of these movies, such as the film Threshold.

Documentaries about the Chernobyl disaster in general, and more particularly, about ill children, abandoned villages, and people living in the 30-km exclusion zone were also made by Western companies and TV programs, and raised their countries’ awareness of the catastrophe and instigated movements to help Chernobyl victims.

In the period of the fall of 1988 to the winter of 1989, an almost-free election campaign began for People Deputies of the USSR (the role of People Deputies was to some extent similar to the role of parliament members in Western democracies). In their political platforms, many of the candidates asked for information about the Chernobyl disaster. For example, Alla Yaroshynska from Zhytomyr Oblast wrote in her program:

“It is necessary to publish data on the consequences of radioactive contamination in Narodichi district, which are thoroughly hidden from the people. There are many villages with extremely high levels of radiation. On radioactively contaminated areas new construction has been organized, and more than 50 million rubles have been already invested. It is necessary to investigate the usefulness of this construction.”

A real fight against governmental secrecy and for benefits to be given to victims of the Chernobyl disaster was launched at the start of the first Congress of People Deputies of the USSR, which took place from May 25 to June 10, 1989, in Moscow. People Deputies from
Ukraine—Volodymyr Yavorivsky, Yuri Scherbak, Borys Oliynyk, Alla Yaroshynska—raised their voices in behalf of those suffering from the accident. Acceding to some of the pressures, the USSR government decided to declassify information about the catastrophe just before the Congress got under way, on May 24, 1989. (Unfortunately, it was easier to reveal the truth than to really help the victims.) More barriers to the spread of information about the catastrophe fell in 1989 when the documentary *Micro-phone!* was shown in the West. Later that year, Volodymyr Yavorivsky openly spoke in the USA about the consequences of Chernobyl, Yuri Shcherbak was invited to hearings in the Swiss Parliament (preparatory to a Swiss vote on the future of its nuclear industry), and Alla Yaroshynska participated in a big antinuclear conference in France.

It was clear at this time that much had to be done in coping with the problems of Chernobyl. But it was also all too obvious that the Soviet Union Central Government’s public purse was empty, and that Ukraine had to forge its own Chernobyl policy. This was the task for the new Verkhovna Rada (Parliament) of Ukraine elected in 1990. In their political programs hundreds of candidates for the Ukrainian Parliament had raised Chernobyl-related issues, especially in regard to the accident victims. With these sufferers having become a major political concern, laws intending to ameliorate their conditions were adopted. But money was required, of course, to implement these plans. Because of the grave economic crisis then facing Ukraine, a special Chernobyl tax was passed to meet the expenses incurred in the efforts to lessen (or “liquidate”) the catastrophe’s highly unfortunate physical and social consequences. Here we set aside the question of how effectively this money was spent.

**State Activities Intended to Resolve the Chernobyl Victims’ Problems**

*Issues Regarding the Evacuation of Contaminated Areas and Compensations Given*

The USSR was not at all prepared for a disaster on such massive a scale as the Chernobyl catastrophe, and most of the government’s necessary decisions regarding the accident were taken only as they were needed. Fortunately, fairly adequate material and financial resources were available right after the event, and executive mechanisms—principally an “undivided union” of the party, the state, and the army—were in place to direct the efforts. In this system the executive power of the USSR, the Council of Ministers and the numerous ministries, was virtually independent of the Supreme Soviet (the Soviet Parliament) until 1989. However, these executive mechanisms did not function very efficiently, and their quality deteriorated quickly, to a considerable extent because of Chernobyl itself.
Some of the early decisions having to do with compensations for the evacuees and the employees of the nuclear power plant were taken by the Central Committee of the Communist Party and the Council of Ministers of the USSR. Those relocated from the disaster zones received insurance-like payments for their houses together with one-time gratuities of up to 4,000 rubles per person (a sum less than the real cost of the abandoned households), whereas the plant workers were given a higher compensation. Of course, the women who underwent abortions during their evacuation or in the first weeks after the accident were not compensated for their suffering. We cannot say how many such women there were and have no reliable information as to what criteria were employed in deciding whether an abortion was or was not recommended to pregnant women, although the question of the desirability of abortions was widely discussed at that time in all of the areas around Chernobyl, including Kyiv (Kiev). It is known, however, that soon after the accident, 2,000 medical teams examined 135,000 people evacuated from the 30-km exclusion zone, paying special attention to children and pregnant women.

Information available to me indicates that by mid-August 1986, 90,784 Ukrainians had been evacuated from the region around Chernobyl. (6) Following ordinances issued by the Council of Ministers of Ukraine, more than 11,000 one-family houses were built to accommodate many of those from rural areas. In addition, people from the cities of Pripyat (50,000) and Chernobyl (12,000) received apartments in Kyiv, Chernigiv, or in other cities of Ukraine and the other Soviet republics. Quite a few evacuees moved in October 1988 to the city of Slavutich, built for the personnel of the re-started Chernobyl nuclear power plant.

Speckhard’s chapter discusses some of the psychological difficulties these people experienced, as was mentioned before. There were also a great many abuses in the distribution of apartments, benefits, and compensations. (It should be noted that quite a few of those who believed they had been wronged sought redress by writing letters to prosecutors’ offices, local and central party committees, and the Councils of Ministers, and their complaints were often supported by People Deputies, journalists, and some public organizations.) There were also physical problems. The quality of the newly constructed houses was often poor so that, for example, the inhabitants were frequently cold and wet. On top of all this, a good number of the evacuees were also disturbed by the great difference between the physical nature of their present resettlement area and that of their now-contaminated, former countryside; as an example, they now saw steppes around them rather than the woodlands to which they had been accustomed. It is not surprising, then, that some evacuees moved back to their abandoned villages. By the autumn of 1988, more than 1000 once again people lived in the 30-km exclusion zone, mostly older people and pensioners. (Some assistance was provided for them by the administration of the 30-km zone and, from time to time, they received shipments of humanitarian aid.)
Even the residents of the privileged city of Slavutich, built by the joint effort of eight Soviet republics, suffered from a lack of medical care, poor food supply, and uncertainty. The council of the Slavutich public organization Pripyat Society, composed of more than 2,000 former inhabitants of the city of Pripyat, sent numerous appeals to the authorities seeking vital information: “Who will determine what radiation doses we had really received?” “Who will organize the medical treatment and recuperation facilities our children need? Many of them are ill.” “When will we receive compensations for the damage to our health?” “The city of Slavutich is located in a radioactively-contaminated area. Will we be given compensatory privileges?”

Similar issues were raised by the people in many other areas, such as Narodichi, Ovruch, Polisske, and others. They pointed out that the levels of contamination in their communities were too high for safe living, and asked why funds should be invested there. Their argument essentially was as follows: “In our district of 25,000 people, 67 million rubles have been spent for new construction. An expenditure of 37 million is planned for this year. Easy calculations show that these sums would allow the construction of 90 five-story apartment houses that would provide the entire rayon (district) with housing. Why should this money be invested here when decisions are made about evacuating people from this area? Who benefits from these wasted millions? …Why should someone have to supply us with ‘clean’ food when we could harvest food ourselves in ‘clean’ lands?” There still are no answers to the questions raised. Polisske, and many villages in Narodichi and other districts are now abandoned—after all the effort and expense of decontamination and construction in these areas.

Many people, especially those with children, wanted to be relocated from the contaminated areas. Yet many others preferred to live where they were, although they insisted on infrastructural improvements (gas and water pipelines, paved roads, and medical services) along with financial compensations. The government had to maneuver between these two options—both required huge expenditures of money. After two years of central (USSR) funding, the burden was shifted to the Ukrainian budget.

The issue of whether residents of contaminated areas should be evacuated or allowed to remain where they were with compensations was extremely controversial. And moreover, there were no scientific or legal foundations on which decisions could be based. As the TASS news agency put it in March 1989, “The Ukraine Health Ministry has recommended the evacuation of five villages in the affected area, even though the ministry insisted that there hasn't been any increase in radiation-related ‘congenital anomalies’ or tumors or blood diseases.”

By the end of 1989, the relative ineffectiveness of decontamination procedures had become
obvious and the Ukraine Council of Ministers issued an ordinance allowing people with children under 14 to leave their contaminated villages. Some compensation was also provided for the households left behind. Calculations performed at the end of 1980s had shown that the per capita costs of the compensations and rehabilitation measures for those remaining in the contaminated areas were more than twice as high as the costs of evacuation. In the period 1990 to 1992 the Council of Ministers of Ukraine developed the resettlement program further by promulgating regulations regarding the conditions under which mandatory or voluntary evacuation from contaminated areas would occur and when compensations should be given to those remaining. There were over thirteen thousand persons who were required to leave their homes and 58,700 “voluntary” resettlements in 1990-1991. As a consequence of all this, by 1995, less than one half of the pre-disaster population lived in 57 Ukrainian villages and communities around Chernobyl, not counting those settlements from which everyone was evacuated.

State Efforts to Deal with the Consequences of the Chernobyl Accident

The Liquidators

It was readily apparent in the years immediately following the nuclear explosion that much had to be done to ease the grave problems confronting the large groups of Chernobyl victims. The liquidators, those who directly involved in cleaning up (liquidating) the radioactive contamination, were obvious candidates for such help. Quite a few of them suffered badly from poor medical treatment, low pensions, and inadequate compensations for their lost health. Many were invalids but lacked official proof that their diseases had been caused by irradiation during their work in the 30-km exclusion zone. Not surprisingly, all these deficiencies led to hunger strikes in a number of the specialized wards and clinics for liquidators. Increasingly aware of these people’s plight, in March 1990, the Council of Ministers of the USSR and the All Union Central Council of Trade Unions adopted a special provision which defined the status of “liquidator,” stipulated that the persons in this category be given regular medical examinations, and also specified that they should receive some privileges. This provision went into effect on June 1, 1990, when the first certificates were issued to liquidators.

Nevertheless, it was soon obvious that “Soviet justice” was no longer operating and that more realistic mechanisms were required for the program’s effective implementation. During September-October 1989 the Councils of Ministers of the Ukrainian SSR, the Belorussian SSR (now called Belarus) and the Russian Federation developed complex general plans for the “liquidation” (i.e., elimination) of the terrible consequences of the Chernobyl disaster, which
the Supreme Soviet (Parliament) of the USSR approved. In keeping with this planning, on February 28, 1991, the Verkhovna Rada (Parliament) of Ukraine passed a law “On the status and social protection of citizens who had suffered from the Chernobyl catastrophe.” The Parliament also approved the “Concept of safe living on the territories of Ukrainian SSR with high levels of radioactive contamination because of the Chernobyl catastrophe.” At the same time, the Parliament, in deciding how to fund the implementation of these laws, obliged enterprises to pay 19 percent (later 12 percent) of their total wages to a special “Fund for the Liquidation of the Consequences of the Catastrophe.”


This law, passed by the Parliament of the Ukrainian SSR on February 28, 1991, was drafted under great pressure from the “Chernobyl lobby,” People Deputies and organizations representing liquidators and those living in contaminated areas. The law then underwent some serious amendments in 1992, 1993 and 1996, mainly because its application revealed economic miscalculations. (Editors’ Note: The following information about the Feb. 28, 1991 law is a modified and considerably abbreviated version of the author’s original description. Readers interested in the more detailed statement should consult the author’s electronic publication, Tykhyy, 1998.)

The law stated that its purpose was to “protect citizens who have suffered from the consequence of the Chernobyl catastrophe,” and to solve the “problems of a medical and social character which have appeared because of radioactive contamination of the territory.” It also held that the state policies governing the “social protection” of the Chernobyl victims were to be in accord with these principles:

a. High priority was to be given to enhancing the health of the victims of the Chernobyl accident.
b. Those who had suffered as a consequence of this catastrophe were to receive full compensation, and
c. Among the economic methods to be used in improving the Chernobyl victims’ quality of life, they were to be taxed at a relatively preferential rate.

In addition to explicitly giving citizens the right to go to court to protect their interests, the law, especially after its 1996 amendments, established four categories of Chernobyl victims in terms of the amount of damage that had been done, or could be done, to their health because they
worked or had lived in contaminated areas. These groupings determined the level of “general compensations and privileges” they received. Category 1 consisted of those who a special medical commission located in oblast centers certified to be now disabled as a result of the Chernobyl catastrophe. Nondisabled liquidators were placed in either category 2 or 3, depending on the period and duration of his/her work in the liquidation process. These times had to be proven by records at the enterprise giving him or her the work assignment.

All of these records at the enterprises were not always kept in proper order, resulting in numerous cases in which people could not be categorized appropriately. Even more frequent were abuses to the system and the use of false documents. Lyubov Kovalevskaya reported that when the records of 14 category-2 liquidators, who were high-level trade-union officials, were examined, only half of them actually had proof their category placement was correct. Because of these problems, in 1996, the state launched a campaign to verify the documents of both liquidators and victims.

**The Victims**

The classification “Chernobyl sufferer” was based largely on the level of radioactive contamination of the soil in the person’s area, as well as the length of time he or she had lived there. In regard to the former criterion, Ukrainian law established four territorial zones, primarily in terms of their radiation level. The worst of these, Zone 1 (or the “exclusion zone”), was the area from which people were evacuated in 1986. The residents of Zone 2 also had to be resettled even though this area had a somewhat lower contamination level. Resettlement was guaranteed for those in the still less radioactive Zone 3, but it was up to them whether they moved or not. And finally, an area was classified as Zone 4, the “zone of intensified radiological control,” if it was contaminated by even lower specified levels of cesium and/or strontium and/or plutonium.

Even with the use of seemingly objective criteria, because of a concern to provide social protection to the catastrophe’s victims, in the period between 1986 and 1995, the number of people given this status increased from 540,000 to 940,000 in 1990 and to 3,200,000 in 1995. In this latter year, 997,000 children were categorized as “sufferers,” based on a somewhat complicated set of considerations. By law, they were given priority for medical treatment at the best medical and recreational facilities. All in all, Ukraine’s social protection system stipulated greater privileges the greater the level of “suffering” that was established by the various criteria: better health care, more access to the better recreation facilities, more material resources such as housing, reduced charges for water, heat and electricity, and better chances of admission to the best schools and universities. They could also obtain extra payments to their pension at a
younger than usual age. As an example, the age at which pensions would begin was reduced by eight years for sufferers in category 2, so that men in this grouping can become pensioners at 52 instead of 60. They also receive an extra monthly payment of 30 percent of the minimal pension.

Of course, a substantial bureaucracy had to be established to implement the regulations and monitor compliance to them. At the time, the basic law was passed the State Committee on Chernobyl (later called the Ministry of Chernobyl) was created to manage what was done. But in addition, local authorities with all their infrastructure and ancillary activities (social care, medical care, etc.) were also greatly involved in carrying out the rules and procedures. Special “Chernobyl” departments were organized in rayon (district) administrations and these now have the main responsibility for regulating and dealing with the sufferers.

**Problems in the Implementation**

Despite what was stated in law, the victims did not always obtain the benefits to which they presumably were entitled. Shortages frequently resulted in eligible persons waiting for housing or the free hospital beds they needed. Many disabled sufferers could not obtain the cars promised them, and quite often, where the classified victims were entitled to medicines free of charge, they found their pharmacies did not have the prescribed medicines in stock. There were also serious problems in financing the construction of housing and its related infrastructure for the resettled evacuees. The state expenses required for this construction were so great (up to 15 percent of all state capital investments) that the construction goals frequently were not achieved: Only 19 percent of the 1992 resettlement program was completed, for example, as was only 28 percent of the program of housing construction.

Other difficulties had to do with unjust violations by the benefit recipients. Some privileges given the liquidators and sufferers, such as the liquidators’ tax exempt status or the classified groups’ right to import goods free of charge, were clearly abused. Not a few newspaper articles told of liquidators or sufferers who managed to import new cars every second week. There were also enterprises that imported substantial amounts of foreign goods duty free and then sold these products in violation of the law’s intent. In their defense, these enterprises usually claimed that the money they gained was used for the “protection of the sufferers of Chernobyl disaster,” but their claim was often difficult to verify. With all of the difficulties in policing the taxation and import privileges, these particular benefits were soon revoked.

Yet another problem arose from the so called “socialist distribution system” governing the
dissemination of goods. At that time (and sometimes now too) the state was the biggest owner of housing, and the communication (principally telephones), educational, and transportation systems. Because of this pervasive government ownership, relatively easy access to these services and facilities was readily set up by law as a benefit. Abusive queue jumping then became all too frequent. Liquidators could even buy motor boats and vacuum cleaners “out of queue.”

Then, too, some benefits established in absolute monetary terms were substantial when the law was first passed, but many of them became economically trivial with the passage of years. One example is the special payment for food free of radioactive contamination; in Zone 3 this monthly extra payment is a negligible 2.10 hryvna (worth $1.1 at the time of this writing). The end result in these cases is mainly extra paper work for accountants.

There is a good reason why these payments cannot easily be increased. The costs of the compensations, privileges, and direct expenses incurred in liquidating the consequences of the catastrophe have been an incredible burden on the Ukrainian economy. Their share of the budget of Ukraine was 15.7 percent in 1992, 10.9 percent in 1993, 5.4 percent in 1994, and 3.4 percent in 1995. Most of this money, about half of the funds allocated for Chernobyl-related matters, has been spent on compensations, with another 20 percent going to resettlement expenses, 9 percent to health care, and 5 percent to the maintenance of the “sarcophagus” (shelter) over the ruins of the exploded power plant and other exclusion zone expenses. The money for all this was collected by the special “Chernobyl fund” tax of 12 percent of wages levied on enterprises. But even with this special source of funds, the Ukrainian Parliament and Cabinet of Ministers have been under intense pressure from all sectors of society.

The needs for social protection, medical care, education, and so on, are widespread throughout the country and not only in Chernobyl-related areas. For people in other sections of the nation, the relatively great amounts of money spent on Chernobyl victims look unfair. Why are they getting so much? What about other areas of the country afflicted by environmental crises, such as the heavily polluted cities of Dniprodzerzhynsk or Mariupol? Why aren’t other children, those from outside of the Chernobyl regions, who are also losing hair and becoming bald, probably because of chemical contamination of their air, water and food, not getting as much attention? This acute problem is still far from being resolved.

Non-Governmental "Chernobyl" Organizations

Ukrainian writers initiated the first campaigns seeking to disclose the truth about Chernobyl in Ukraine. As a major example, in 1988, they established the first non-governmental organization (NGO) emphasizing ecologically friendly (“green”) policies, Zeleny Svit (Green World), an asso-
ciation of numerous organizations in many oblasts and districts of the country. Chernobyl-related problems of course had the highest priority for this NGO. The next year another network of small NGOs, called “Salvation from Chernobyls” and mainly in contaminated areas, became part of Green World. These NGOs played an important role as pressure groups. Serving as vox populi, they aided the attempts by people deputies and local authorities to redistribute resources in favor of the contaminated regions. Local politicians also used support from these groups in their election campaigns and legislative work.

Later in 1989 an antinuclear, anti-Chernobyl march was jointly organized by Green World and the Ukrainian Movement for Perestroika, Rukh. The march started at Khmelnytska nuclear power plant in Western Ukraine and ended in Kyiv (Kiev). Rallies took place in numerous villages and towns along the route in which people protested against the secrecy in Chernobyl affairs, demanded fair compensation for the victims, and insisted on clean food, medicines for the sufferers, and the evacuation of children from irradiated areas. In addition, more than 300,000 people from five oblasts signed an appeal to the Supreme Soviet (Parliament) of the USSR. This signed appeal was taken to Moscow and given to Ukrainian members of the Parliament who used the document to push the badly needed Chernobyl legislation through the Parliament.

Another of Green World’s important projects was an independent Chernobyl investigation (from 1990 to 1992) in which a number of lawyers, witnesses to the accident, and others participated. Modeled to some extent on the Nuremberg trials, this project was an attempt to provide a formal appraisal having legal standing of the actions of government officials and others responsible for the Chernobyl disaster as well as for the clean up afterwards. The investigation, ideally, would have allowed the victims of the Chernobyl catastrophe to sue the state, officials, and/or plant managers in courts so that they could obtain a just compensation for their loss of health and/or property. Unfortunately, very few lawyers agreed to take part in this project so that the evidence presented and the legal arguments offered did not have sufficient credibility to the public at large. Also important, quite a few of the government officials whose decisions contributed to the accident are still active politicians, and it is likely that they would not have allowed the process to get very far.

Where Green World worked primarily with the population of contaminated areas, another NGO, Chernobyl Union International (CUI), founded in Ukraine in 1989 and registered as an international organization in 1991, had a similar role for liquidators and evacuees. CUI’s primary aim, as stated in its founding statute, was “to address and mitigate the consequences of the accident... by assisting the 1.5 million direct victims of the Chernobyl catastrophe, including children...
and those disabled due to the effect of the explosion, to deal with the extraordinary social, economic and medical needs they are facing.” In accord with its stated purposes, the NGO had an important part in initiating and drafting laws concerning the status and social needs of Chernobyl victims. Helping it fulfill its goals, the CUI president at this time, Volodymyr Shovkoshytyny, was a People Deputy of Ukraine.

The funds enabling this NGO to carry out its activities were provided by charitable organizations abroad, particularly the Bavarian Red Cross and the governments of some German provinces and cities. But by and large, CUI has not been the direct recipient of aid, but has served mainly as the facilitator and coordinator of relief to institutions, hospitals, clinics, and so on. An important and still ongoing CIU program has to do with the organization of children for rest and recuperation abroad. (To provide an indication of this project’s scope and growth, 231 children were involved in this particular project in 1990, 1520 in 1991, and 1800 in 1992.) All in all, the cost of goods and medicines distributed by CUI in Ukraine amounted to tens of millions dollars (in comparison to the $1,500,000 collected at the UN Conference in 1991).

Finally, it is also worth mentioning the various charitable foundations and enterprises organized by people having the status of Chernobyl sufferers whose activities should be carefully monitored. A good number of these organizations enjoy substantial benefits (including reduced taxes), but their privileges derive primarily from decrees and ordinances issued by Cabinet Ministers, which were often applied selectively, rather than specifically from the Chernobyl legislation.

**Some Concluding Remarks**

The author is well aware that this short report covers only a fraction of the multiplicity of factors involved in the Chernobyl disaster and its aftermath. Much of what has been said here is based on the writer’s experiences, information provided to him by a variety of sources, and publications generally available. But there also are new documents now coming to the fore, material that can provide valuable insights into the causes and consequences of this catastrophe. The author also believes that a truly complete understanding of what happened in the past and what is now occurring in regard to Chernobyl requires a really deep and unbiased analysis of the relevant roles of many important players, such as the International Atomic Energy Agency, the United Nations and its components, and international “green” and anti-nuclear organizations, as well as the internal Soviet nuclear lobby and the opposing Soviet “green” and public movements. Maybe it is still too early for such an in-depth analysis simply because the drama is not
finished yet and many actors are still on the stage.

Of course, a comprehensive picture also necessitates the collection and publication of information about all of the people of good will around the world who have aided the victims of the Chernobyl catastrophe in one or another way, through official structures and purely unofficial and private actions.

References


Endnotes

1. This is a revised version of Volodymyr Tykhyy’s paper, “Chernobyl sufferers in Ukraine and their social problems,” first appearing in the 1998 publication, Chernobyl Report, KURRI-KR-21, edited by Dr Tetsuji Imanaka of the Kyoto University Research Reactor Institute. Some of the information given in the present version was not in the original electronic publication but has been added to provide more details about the Chernobyl
catastrophe and its aftermath. By and large, this added material is printed in italics. Other sections of the original paper, such as those spelling out the details of legislation prescribing the benefits to be given to the liquidators and the Chernobyl victims, have been greatly abbreviated, while still other material, especially that describing international efforts in behalf of the sufferers, has been omitted altogether as outside the intended scope of this chapter. Readers interested in these matters should consult the original publication.

2. A statement by the author: This report is based both on materials published in the Soviet Union and Ukraine and on author's personal experience. It does not pretend to be a complete examination and description of all of the official and social activities in Ukraine related to Chernobyl disaster.

In 1987-1989 the author worked as physicist in the 30-km zone and in other contaminated areas. This enabled him to meet many people at different levels of society (administrators, collective-farmers, "self-settlers" etc.). In 1988-1991 the author was an active board member and researcher of the Ukrainian Environmental Association "Zeleny Svit" (Green World), the biggest and most influential Ukrainian NGO at that time, headed by the People Deputy of the Soviet Union, later Ambassador to the United States, M.D. Yuri Scherbak.

In 1991-1993 the author worked as a project manager and director of the Greenpeace Ukraine office. That was the time when Greenpeace ran a medical assistance project and also carried out an independent investigation of the radioactive contamination in Zhytomyr oblast. These activities required frequent contacts with the Ministry of Health of Ukraine and members of Ukrainian Parliament, as well as with people in contaminated areas. The author also participated in some humanitarian projects, mainly with Swiss and German partners.

Being a “participant of the liquidation of the consequences of Chernobyl catastrophe, category 2A,” the author has also had personal experience with the system of social assistance. At the time this revision was written Mr. Tykhyy was a self-employed consultant.

3. There is considerable disagreement as to how many emergency workers lost their lives as a direct result of the catastrophe. In the summer of 1986 Soviet officials listed 31 fatalities (and two years later maintained that 238 people had suffered from acute radiation syndrome [Medvedev, 1990, p. 129]), whereas other observers insisted that 15,000 had died in the Kiev hospitals alone within five months (Marples, 1988, p. 35). Marples, a contributor to the present volume, maintained (in 1996) that the official toll of 31 is a “mythic figure.” He believed a 1995 estimate, offered by the National Committee for Radiation Protection of the Ukrainian Population, that over 5700 liquidators had died, was “far more reliable.”

4. The 15-year report of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) estimated that about 116,000 people were evacuated in Belarus, Russia, and Ukraine, although this figure evidently does not included children from some regions. Writing in 1997, Marples estimated that almost 250,000 people in the Soviet Union had been permanently relocated from their homes as a consequence of Chernobyl.
5. The Soviet government was slow to warn its endangered citizens of the precautions they should take to minimize their chances of being harmed by radiation, such as avoid drinking milk and eating fresh vegetables. It wasn’t until May 6, 11 days after the nuclear explosion, that Kiev radio advised against eating leafy vegetables and recommended that people should remain indoors as much as possible (Gregorovich, 1996).

6. The official report held that over 90,000 people were evacuated from the dangerously irradiated zones in Ukraine within a year or so (see Marples, 1988, p. 31).
Chapter Six

IDENTITY AND MEANING: CHERNOBYL IN LITERATURE

Jennifer Ryan Tishler

Catastrophe,” observes Sidra DeKoven Ezrahi, “is that liminal condition which tends to strain the forms and procedures by which reality is composed or decomposed in art.” (1) The 1986 explosion at reactor number four of the Chernobyl Nuclear Power Station in Ukraine challenged writers of novels, poetry, and drama to join journalists and scientists in attempting to explain the catastrophe. Within months of the explosion, works appeared in many different genres, including the novel, the short story, drama, lyric poetry, and even one example of a *duma*, the traditional Ukrainian epic poem sung by a *kobzar*, or minstrel. (2)

In this chapter, I will demonstrate several ways in which literary responses to Chernobyl construct meaning from that disaster. Although my brief study will include works of different genres (drama, lyric poetry, short story, and novel), this chapter does not attempt to present a survey of all Chernobyl-related literature. Given the goals of the present volume, I limit my analysis to four works that have appeared in English translation: Vladimir Gubarev’s play *Sarcophagus*, a collection of poems by Liubov Sirota, Andrey Fedarenko’s short story, *Bliakha, or After Chernobyl*, and Svetlana Aleksievich’s documentary novel *Voices of Chernobyl*. 

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Four Views

To illustrate how these seemingly disparate works relate to one another, picture a series of concentric rings radiating out from the nuclear power station, with the smallest ring representing the time closest to the event. As the earliest work and the one concerned most urgently with the events of April 1986, Gubarev’s *Sarcophagus* occupies the smallest, closest ring. The next ring holds Sirota’s 1990 collection of poetry, which is more retrospective and comprehensive than Gubarev’s play, but still expresses an acute sense of outrage. The third ring is taken up by Fedarenko’s short story. Published in 1994, “Bliakha” depicts Chernobyl not as the singular cause of the characters’ despair, but as part of a larger pattern of misfortune. Finally, the ring furthest from the plant holds a work that incorporates elements of the earlier three: Aleksievich’s 1997 documentary novel. When we reach Aleksievich’s work, the sense of immediacy and alarm of *Sarcophagus* has fully given way to the ambiguity and desolation of living in the aftermath.

Despite their diversity in genre and date of composition, all the works in this survey challenge readers to consider the broad theme of *identity* (and the transformation of that identity) in the wake of Chernobyl. Sometimes this theme emerges as dialogue between the self before and after Chernobyl as characters come to terms with loss: loss of loved ones, loss of health, loss of home. The theme of identity also includes considerations of national identity and nationhood in the Soviet Union and the post-Soviet successor states. A third aspect of this theme identifies the victims and the perpetrators of the Chernobyl disaster. Although all four authors raise questions of guilt and culpability, they come to different conclusions about where to draw the line between these two categories.

One of the most fundamental issues of identity concerns who maintains the right to tell the story of Chernobyl. In times of catastrophe a contested form of discourse emerges as different voices compete for what Susanna Hoffman and Anthony Oliver-Smith term the “ownership” of the disaster: “the right to claim that it occurred, who its victims were, and the ‘true account’ of events, origin, consequences, and responsibilities.” (3) Readers are often tempted to privilege immediate eyewitness accounts over narratives and analyses created with the benefit of hindsight and retrospection. The most valid stories, this way of thinking goes, belong to those who witnessed first-hand the events of the disaster. Indeed, personal written reactions to shared public tragedies allow even distant readers to identify with an eyewitness to war, genocide, a natural disaster, or a technological disaster like Chernobyl. Nonetheless, we as readers should temper our natural appreciation for the immediacy of eyewitness testimonials with an understand-
ing of their limitations as factual documents. Those who are closest to unfolding events can be misled in the very act of witnessing, suffering misperceptions brought on by extreme conditions or even the deliberate dissembling of those who control the flow of information. Speckhard’s chapter in the present volume offers a closer psychological analysis of the misperceptions that can arise in the aftermath of a calamity.

This phenomenon has been recorded in studies of the witness-diarists of the Holocaust. Historian James Young, for example, warns readers to question the apparent verity of eyewitness accounts from the Nazi concentration camps:

But where the writing from within the whirlwind may be ontologically privileged insofar as it is empirically linked to events, it is not thereby more ‘real’ or ‘authentic’ if these terms denote factual veracity. Indeed the horrible irony is that, as nearly all the diarists and many of the survivors remind us, their insights, interpretations, and eyewitness descriptions may even be less reliable in a “factual sense” because of their proximity to events. (4)

Young’s warning is relevant to reading literature about Chernobyl. In the first hours after the explosion, the observations and actions of many eyewitnesses were colored by the conviction that an accident of that magnitude was impossible. Grigorii Medvedev, in his engaging narrative of the accident, illustrates the power and reach of the “nonsensical but extremely comforting idea that the reactor was still intact,” even in the face of visual evidence to the contrary. (5) Medvedev cites the testimony of a shift foreman by the name of Viktor Smagin:

Lyutov, the deputy chief science engineer, [. . .] kept on repeating that if only someone would tell him the temperature of the graphite in the reactor, he would be able to explain everything. I asked him, in amazement, what graphite he was talking about, and pointed out that practically all the graphite was on the ground. [. . .] I hammered away relentlessly at the same point. “Look! Graphite blocks—you can make out all the details. [. . .] The holes in the middle are where the fuel channel used to go. Can’t you see?” “Yes, I see. But is it really graphite?” Lyutov continued to doubt my word. (6)

The challenge of witnessing the Chernobyl catastrophe was complicated by the incomplete or imprecise information given to those who were closest to the center of the accident. During the effort to extinguish the fires and construct the “sarcophagus”—the containment shell of concrete and steel around the fourth reactor—members of the clean-up crew (sometimes termed “liquidators”) were not told the full extent of the danger they faced. For instance, facing a critical shortage of equipment, liquidators were made to remove radioactive material by hand, often with little or no protective clothing. One of the speakers in Aleksievich’s Voices recalls: “Even the ones who were putting out the fire at the reactor later realized that they were living amid
rumours. Living on rumours. It seemed that it was dangerous to handle graphite. ... It seemed ... it seemed.” (7) Through repetition of the phrase “it seemed” (in the Russian original, “kazhetsia”) the speaker reveals a fatalistic pessimism in the willingness (or obligation) of higher-ups to provide their subordinates with accurate information.

Although many who were closest to the disaster question the veracity and totality of their own accounts, they still value their status as eyewitnesses. One soldier explains, “Besides us, no one knows what went on there. We did not understand everything, but we saw everything.” (8) Recalling his father’s participation in the defense of Moscow during the Second World War, a member of the clean-up crew concurs, “I haven’t told you anything. Just fragments. [. . .] Is that the way it always is? [. . .] My father defended Moscow in 1941. He understood only decades later what a great event that had been. From books and films.” (9) This admission challenges the popular notion that personal experience trumps other ways of knowing. Rather, the veteran’s story confirms the role of external, retrospective narratives (in this case, literature and film) in contextualizing and rounding out private memories of lived experiences.

Initial literary responses to Chernobyl shared an impulse to get to the “truth” of the accident and to determine who was to blame for the mistakes made before and after April 26, 1986. Gubarev, the author of Sarcophagus, wrote: “There is only one way of avoiding a repetition of Chernobyl: to tell the truth about what happened, to make the most painstaking analysis of the causes of the tragedy—and to not let the culprits get away with it.” (10) This search for truth, mirroring actual Chernobyl hearings and trials, was also a general characteristic of literature of the glasnost period. Although Mikhail Gorbachev’s policy of glasnost (or openness) predated the Chernobyl accident by several months, it was only put to the test in the aftermath of the disaster. As David Marples (one of the contributors to the present book, writing in 1988) points out, “Chernobyl is not officially part of the glasnost campaign, or, to put it more accurately, the openness about certain facets of Chernobyl has occurred without the blessing or guidance of the authorities.” (11)

When it was first introduced, the policy of glasnost was not meant to allow for complete freedom of expression. Rather, it was promoted as a way to achieve a more perfect socialism through an open exploration of formerly-hidden problems, such as alcoholism, prostitution, and drug abuse. Mikhail Gorbachev and his reformers called for openness and pluralism in cultural life, criticizing the Communist Party’s previous imposition of a lacquered view of society. Gorbachev encouraged writers and other members of the intelligentsia to participate constructively in debates about the future, which, however, he always viewed as the socialist future. Moreover, glasnost as a policy was not promoted evenly throughout the Soviet Union, a significant
fact when we consider the Chernobyl literature produced in the Ukraine or Belorussia. Yuri Shcherbak, a medical doctor who later served as Ambassador of Ukraine to the United States, wrote Chernobyl: A Documentary Story soon after the accident. Shcherbak’s Chernobyl first appeared in Russian in the summer of 1987 in the monthly journal Iunost’ [youth]. The novel was not published in Ukrainian until the spring of 1988. (Tykhyy’s chapter in this book also refers to Shcherbak’s efforts, along with other Ukrainians, to help spread information about the Chernobyl disaster.)

In his preface to the Ukrainian version, (from which the English translation was made) Shcherbak explains that he first published the story in Iunost’ rather than in a Ukrainian journal because he saw Chernobyl not as a regional problem but as a Soviet or even global catastrophe. Because he wanted his story to have the broadest possible reach, he agreed to publish it in Russian in a journal with distribution throughout the Soviet Union. Shcherbak’s decision to forgo an initial Ukrainian-language publication was also shaped by the uneven application of glasnost in different areas of the Soviet Union. Regional leaders were wary, at first, of going too far, and so a safe bet was to follow, rather than anticipate, the level of openness allowed by Moscow. “One thing was permitted ‘in the centre’ and another—far less of it and far worse—in the localities.” (12) An American folklorist who traveled to Ukraine in 1987 noted: “While there was a noticeable loosening of restrictions in Russia, in Ukraine constraints were, if anything, more severe.” (13) Larissa Onyshkevych concurs:

Since the nuclear fallout could not be concealed from the world, glasnost rode […] on the crest of demands for real facts about the actual scope of the disaster. Chornobyl also demonstrated to the world that the proclaimed glasnost was not really in force even at the end of May 1986, nor was it applied equally throughout the USSR. (14)

**Vladimir Gubarev’s Sarcophagus**

The publication of Vladimir Gubarev’s play Sarcophagus illustrates the uneven reach of glasnost in the Soviet Union. As the science correspondent for the newspaper “Pravda,” Gubarev was sent to cover the Chernobyl accident and was one of the first journalists on the scene. In addition to filing reports for “Pravda,” Gubarev, according to Michael Glenny, was expected to write “a longer piece, more analytical and more reflective” to be published in the monthly journal Znamia [“The Banner”]. (15) Gubarev carried out his research for the longer analytical piece, but what emerged instead was the play Sarcophagus [“Sarkofag”], whose title comes
from the shell built to cover and seal the exploded reactor. The genre of *Sarcophagus* is significant to its creation and its dissemination. Through drama, Gubarev effectively presents many voices, recreating the confusion and misinformation that emerged in the days immediately following the accident at Chernobyl. Moreover, the author hoped that a staged play would reach a wider audience than a published essay or story could.

Gubarev wrote *Sarcophagus* in a mere seven days. Completed on July 5, 1986, *Sarcophagus* has been recognized as “the first literary output to emerge from the Chernobyl accident.” (16) The play is set in a Moscow research institute—the Institute of Radiation Safety—where victims of radiation sickness are studied and treated. First, we meet the doctors and research scientists; in the middle of the first scene, they are joined by survivors of an explosion at “Reactor Number Four” (Chernobyl is not named at the moment of the accident). Driving the action are the emotion-laden encounters among the various patients, who are a sampling of Soviet “types.” They include plant personnel, such as a control-room operative, a firefighter, and the director of the nuclear power station, as well as those who simply had the misfortune of living in the vicinity of the disaster, such as a peasant woman named Klava and an athletic petty thief known only as the Cyclist.

Gubarev endows several of the characters with symbolically weighty names. For example, one patient at the institute is named Bessmertny [Immortal]. Alone among the patients, Bessmertny is not a victim of the accident at Reactor Number Four, but in an earlier mishap at a nuclear laboratory had received what should have been a fatal dose of radiation. Against all odds, he has remained alive for 487 days after this exposure when the play opens. Bessmertny (an alias of his own choosing) also calls himself Krolik [“rabbit,” i.e., a laboratory rabbit].

Bessmertny has cheated death at an enormous cost: He is forbidden to have any contact with family and loved ones from his past. In effect, his past self has died and the being who survived as “Bessmertny” is trapped in a permanent present, with no past and no future. He dwells from day to day within the antiseptic walls of the institute. Demonstrating that he is now completely cut off from his earlier life, Bessmertny refuses to reveal his true name: “Let’s say I’ve forgotten it.” Also noteworthy are the names of three young doctors assigned to work at the institute: Vera, Nadezhda, and Liubov (respectively, Faith, Hope and Love). Significantly, it is Vera (Faith) who volunteers to work with Bessmertny, while her colleagues Liubov and Nadezhda ask to be assigned to the greenhouse, away from the suffering of human patient-subjects. Unable to cope with the stress of caring for people with acute radiation sickness, Nadezhda quits her job and departs from the institute, signifying the early loss of hope in the play.

Because *Sarcophagus* was written shortly after the event it describes, the play has a certain
immediacy and earnestness not found in the later works. Readers, however, should not expect an accurate portrayal of the Chernobyl accident. This is, after all, a work of fiction. Moreover, although Gubarev aimed to endow his creative work with a strong factual foundation, he wrote *Sarcophagus* before the August 1986 hearings of the International Atomic Energy Agency (IAEA), when details of the explosion’s cause were revealed. In the play, the Physicist refers to the reactor as a “perfect device [. . .] a miracle!” (18) and places the blame for the accident not on the reactor’s flawed design, but on the incompetence of the control-room operatives, echoing early official assertions that the explosion was caused by a poorly-executed experiment. The Physicist asserts: “Because the emergency system had been switched off, the rise in temperature led to the first, small explosion.” (19) As was revealed at the IAEA hearings, according to Marples, “the accident, strictly speaking, had not arisen because the safety devices had been switched off, as the play implied. These actions made the original experiment less safe, but they did not cause the disaster.” (20) (Corradini’s chapter in this volume provides a more detailed discussion of the inadequacies and dangers in the Chernobyl reactors’ design.)

Throughout the play, the threat of nuclear war looms as an ancillary plot to the Chernobyl catastrophe. This subplot is played out through a motif repeated at the end of each scene: an off-stage male voice (meant to represent a radio broadcast) offers official instructions on what to do in the event of a nuclear war:

“The threat of a nuclear attack will be announced immediately on the radio, on the television and in the press. Wherever you may live, [. . .] take immediate protective measures.” (21)

By including these snippets of the official voice, Gubarev comments ironically on the scarcity of reliable information immediately following the accident at Chernobyl. The sudden attack of the civil atom, the “peaceful” atom (as it was known in Soviet propaganda), initially stunned the Soviet leadership into silence. As victims of the explosion at the power station are being brought to the institute, Bessmertny remarks, “There’s been nothing about [the accident] on the radio.” (22) When the silence was broken, the first words broadcast about the Chernobyl accident downplayed the seriousness of the situation and gave empty assurances that all necessary steps were being taken. As a result, people did not know, for example, where to get iodine or how to prepare for evacuation. In this context, the announcer’s prepared texts on the necessary steps to take in a nuclear war reveal themselves to be irrelevant.

Gubarev uses the subplot of nuclear war not only to criticize the failings of the Soviet bureaucracy but also to teach a not-so-subtle moral lesson to the United States of America. The character Kyle is based on the real-life Robert Gale, an American surgeon who went to Moscow in order to perform bone marrow transplants on Chernobyl firefighters suffering from acute
radiation sickness. In the interplay between the American Kyle and the Russian characters, Gubarev echoes official Soviet rhetoric about American nuclear aggression. Near the play’s conclusion Kyle preaches: “The most important thing that you and I must bring home to the world press is that this tragedy at the nuclear power station is a minor incident compared with a nuclear war. We now have a vivid illustration of what it can be like.” (23) Before the American departs, he is warned by Bessmertny: “When you’re back in America, tell your people—the ones with their fingers on the button—that if they ever press it, there’ll be nothing left, nothing.” (24) The theme of the heroes and villains of the Chernobyl accident slips to the background as the play begins to speak out against American (but not Soviet) promotion of the arms race. According to the logic of the play, the peaceful Soviet Union is a victim of a nuclear arms race driven by American perpetrators. The Soviet Union is not to blame for the massive proliferation of nuclear weapons, but must bear the consequences all the same.

While it is possible that Gubarev included this echo of official Soviet rhetoric in order to expedite his play’s progress to print and to the stage, in other published statements he also speaks of the martyrdom and exceptionalism of his people. Gubarev is not alone in his convictions; the theme of Russian (or Soviet) sacrifice to an ungrateful and ignorant West is a commonplace that dates back at least to the nineteenth-century thinker Chaadaev, who bemoaned Russia’s second-tier status as a nation that exists “only to teach some great lesson to the world.” The messianic view of Chernobyl holds that the catastrophe was yet another sacrifice that “we” made (and depending on the speaker, this “we” can signify Russians, Ukrainians, Belarusians, or the Soviet people as a whole) for the sake of the West, which profits from our misfortune. In an interview, Gubarev identifies just such an unspecified “we” (while judiciously avoiding the designations “Russia” or “Soviet Union”). He calls Chernobyl the third most significant event in the history of “our country:”

The first [event] was the Tatar-Mongol yoke. We defended Europe from the hordes and from barbarism. The second was fascism. We saved Europe from fascism. And today we are securing the future of humanity at a very great price. [. . .] And the future of civilization is unthinkable without nuclear energy. But Chernobyl happened. So, when we build the future, we must bear in mind the lessons of Chernobyl. (25)

By comparing the Chernobyl disaster to the Mongol invasion of the thirteenth and fourteenth centuries and to the Second World War, Gubarev places the Chernobyl accident in a larger historical framework and plugs into deeply rooted attitudes and beliefs in the popular consciousness.
In *Sarcophagus*, Gubarev expresses the idea that the West benefits from Russia’s misfortune through Ptitsyna, a surgeon at the Institute who sharply criticizes her Western counterparts for their perceived opportunism:

> I’m fed up that they’re using us. And not for the first time. [...] If you believe what they say in the West, there’s nothing left for us to do but put on a white sheet and walk to the cemetery. But in a few days … they’ll start asking permission to come to the site of the accident. To gain experience at our expense. (26)

At the same time, Gubarev does not seem to object to Soviet scientists’ gaining experience from their study of the Chernobyl accident. The Physicist in Gubarev’s play, for example, views the explosion as a great experiment. With perhaps too much enthusiasm he exclaims: “You see, there has been no such experiment as this in the whole history of science—the explosion of a reactor and its consequences.” (27) The Physicist believes that lessons can be learned from the catastrophe if it can be studied and understood “from every aspect—theoretical, technical, psychological.” (28)

Aware that he is dying, the Physicist insists that his wife and son not be told he was at the power station during the explosion: “Let them find out later. About everything that happened. And about my calculations. They’ll be proud of me… I was the first person in the history of science to do them [the calculations]. It will soften the blow for them….” (29) The Physicist sacrificed his life for the greater good of science. For him, Chernobyl is not a senseless catastrophe, but a vast experiment with the potential to communicate valuable lessons.

Both in the play and in published interviews, Gubarev assigns meaning to Chernobyl. First, the accident can be understood as a warning about the horrors of nuclear war. Second, the accident fits into a larger historical pattern of sacrifices made by the people of Russia, Ukraine, and Belarus. The theme of sacrificing an individual for the sake of the collective or of enduring hardships now to secure a better life for one’s grandchildren ran very deep in the consciousness of the Soviet population. Gubarev taps into that vein through the Physicist and Bessmertny, who demonstrate that the nuclear accident provided invaluable medical and scientific data.

By asserting that a great human lesson can be learned from Chernobyl, Gubarev tries to make sense of the senseless and to counterbalance the profound destruction wrought by the explosion and its aftermath. The model of Chernobyl as sacrifice carries powerful religious connotations that the accident’s victims will receive eventual redemption. In her Chernobyl poetry, Liubov Sirota challenges this view.

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**The Poetry of Liubov Sirota**

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Sirota lived and worked in the Ukrainian city of Pripyat, the settlement closest to the Chernobyl nuclear power station. Both she and her son were evacuated from Pripyat, but nonetheless have suffered from exposure to radioactive contaminants. The director of a writing program for children, Sirota turned to poetry for the first time in the aftermath of the explosion. Her first collection of poetry—*Nosha* [Burden, 1990]—was published in Kiev and contains several poems about Sirota’s trials after the Chernobyl accident, including her evacuation, illness, and loss of loved ones. Paul Brians, who teaches in the Department of English at Washington State University, hosts a website where the Chernobyl poems from *Burden* have been translated into English. (30)

The genre of lyric poetry allows Sirota to write about her experiences in a single voice. In contrast to Gubarev’s play, where the authorial voice is shared among several characters (most dominant in the characters of Bessmertny, the Physicist, and Ptsitsyna), Sirota’s poetry provides a more personal view of Chernobyl. Moreover, unlike Gubarev, Sirota writes from the point of view of someone in the thick of events rather than with the detachment of a journalist-scientist.

In the poem “They did not register us,” (31) Sirota raises the question of the disaster’s ownership and the contested categorization of Chernobyl’s victims. In the poem, some unnamed political or medical “they” fail to count the lyric heroine and her peers among Chernobyl’s official victims (perhaps in order to downplay the scope of the accident and limit the government’s liability for reparations): “No processions laid wreaths, / no brass bands melted with grief. / They wrote us off as / lingering stress, / cunning genetic disorders…”

The lyric heroine in this poem is doubly wronged. While not acknowledged as one of Chernobyl’s victims, she is still treated as a sacrifice for the greater good and made to feel that her sacrifice should bring her serenity. Through bitterly ironic language, the poet rejects this notion of redemption:

> But we—we are the payment for rapid progress,  
> mere victim of someone else’s sated afternoons.  
> It wouldn’t have been so annoying for us to die  
> had we known  
> our death would help  
> to avoid more “fatal mistakes”  
> and halt replication of “reckless deeds!”

In the poet’s view, the deaths and illnesses have been in vain. By linking a word like “annoying” (in Russian, *obidno*) with death, Sirota exposes the lack of regard for individual human life. Quotations like “fatal mistakes” and “reckless deeds” are examples of official ex-
planations for the root causes of the Chernobyl accident. In turn, the poet exposes the emptiness of this officialese and expresses her doubt that future catastrophes can be prevented.

Sirota does not reject entirely the notion that the unacknowledged victims of Chernobyl are part of some larger sacrifice, but she reserves the right to define the nature of that sacrifice on her own terms. In the next poem in the collection, “Peace unto your remains,” the poet prays that no future victims experience this current torment:

\[
\text{May God not let anyone else} \\
\text{know our anguish!} \\
\text{May we be extinction’s limit.} \\
\text{For this, you died.}
\]

Whereas Gubarev asserts that science and medicine will benefit from knowledge gained in the study of Chernobyl, Sirota rejects such a pragmatic view. Unlike Gubarev’s Physicist, Sirota’s poetic persona is not interested in furthering the cause of theoretical science; she wants to prevent future human suffering.

Although the victims cannot atone for the mistakes of Chernobyl, they must bear the burden of suffering all the same. In the three-part poem “To Pripyat,” devoted to the town that Sirota and others were forced to abandon, the poet expresses her sorrow at being forced to abandon her town:

\[
\text{We can neither expiate nor rectify} \\
\text{the mistakes and misery of that April.} \\
\text{The bowed shoulders of a conscience awakened} \\
\text{must bear the burden of torment for life.} \\
\text{It’s impossible, believe me,} \\
\text{to overpower} \\
\text{or overhaul} \\
\text{our pain for the lost home.}
\]

Sirota’s expressed pain in abandoning the native home is a counterweight to Bessmertny’s cavalier announcement, after a year in the institute: “I have no past. I have forgotten everything about it.” (32) The theme of the abandoned home is treated differently by the two authors in other episodes as well. Gubarev’s Klava is concerned about the practical task of taking care of her farm animals, but because she does not yet realize that she will never return to it, she does not express a greater despair for the lost home: “I must go home. My cow, Dasha, hasn’t been milked. [. . .] And the chickens haven’t been fed.” (33) Sirota’s speaker has survived the chaos of the initial evacuation and only now has come to realize the scope of her loss.
When Sirota in her poem “At the Crossing” describes bureaucrats who “babbled on / like crows / about universal good” she recalls some of Gubarev’s more pointed lines about the inefficiency and dishonesty inherent in the Soviet system. In contrast to Gubarev’s dominant and often strident search for the villains of Chernobyl, Sirota acknowledges that for her “It’s unimportant / whose the fault, / what the reason / the sky is boiling only with crows....” Any initial satisfaction at having assigned blame fades to the despair of living in the aftermath. Whereas the most important questions for Gubarev were “Who is to blame for the accident?” and “What lessons can we learn from it?” Sirota asks instead, “How can we go on living after Chernobyl?”

The theme of the power of human memory is much more dominant in Sirota’s poetry than in Gubarev’s play, where Bessmertny must forget his past in order to survive in the present. In “To Pripyat” Sirota writes:

\[
\begin{align*}
At \text{ night, of course, our town} \\
\text{though emptied forever, comes to life.} \\
\text{There, our dreams wander like clouds,} \\
\text{illuminate windows with moonlight.} \\
\text{There, trees} \\
\text{live by unwavering memories,} \\
\text{remember the touch of hands.}
\end{align*}
\]

Forbidden from returning to their town, the displaced population of Pripyat goes back only in their dreams. The town becomes not only the thing remembered, but the locus of memory. This same motif is echoed in the testimonies gathered by Svetlana Aleksievich in her *Voices from Chernobyl*. One of the evacuees she interviews says, “By day we lived in the new place, but at night we were at home. In our dreams.” (34)

In contrast to Sirota’s speaker, who has been evacuated from her village and so mourns its loss from another place, Andrei Fedarenko’s hero “Bliakha,” in the short story by that name, still resides in the abandoned village. And instead of expressing nostalgia for a beloved way of life, Bliakha recalls how he was alienated and shunned by his fellow villagers before the Chernobyl accident.

**Fedarenko, “Bliakha, or After Chernobyl”**

Andrei Fedarenko was born in 1964 in the Gomel region of Belarus, a region especially devastated by radioactive fallout from Chernobyl. His short story “Bliakha, or After Chernobyl” takes place in an unnamed Belarusian village on the edge of the contaminated zone. The village set-
ting of the story is significant in that Fedarenko describes not merely a locale or a collection of buildings (many of which are now abandoned), but more important, a human community. As the story opens, that community has been decimated by forced evacuations and voluntary resettlement. Among the village’s few remaining inhabitants are “Bliakha,” (so nicknamed because he peppers his conversation with this word, a mild profanity in Belarus), an old man who was once a prosperous farmer, and the old man’s wife. Through the interactions and inner thoughts of the three characters, Fedarenko paints a vivid and ultimately bleak picture of human relations. The dying village is a metaphor for the hollowing out of the human soul that began far before Chernobyl, but was accelerated after the tragedy. Chernobyl is not the cause of man’s inhumanity to man, but brings it into sharper relief.

Before the Chernobyl accident, the title character, described as “gentle” and “harmless,” was shunned by his fellow villagers, who avoided and disliked him “as they generally dislike failures in Belarusan villages.” (35) Abandoned by his father, Bliakha was sent to jail when he was in the eighth grade for stealing a moped. Upon his release, Bliakha occupied the lowest rung on the social ladder of his village and performed any kind of menial work in exchange for a drink. Bliakha “lived by himself” (36) and the other villagers often mistreated him. The old man would not allow Bliakha to sing Yuletide carols at his house; the old woman once wrongly accused him of stealing buckets. Rather than caring for its most unfortunate member, the village isolated him, as though his failure were contagious.

The narrator describes the village in anthropomorphic terms, referring to a time before Chernobyl “when the village was still alive.” (37) Following the accident at Chernobyl, both the village and Bliakha are changed, although Bliakha’s is the more unexpected transformation: “It was only after Chernobyl that Bliakha recognized that he too was a human being.” (38) People who earlier had shunned and scorned him now needed his help to load trucks, visit the cemetery, and listen to their lamenting. The villagers, who were once united in their disdain for Bliakha, now “looked at him and talked to him as if he, a stranger, were their closest relative.” (39)

The passage continues: “For the first time he read in their eyes not disdain, but something more like guilt, and the very love that he had missed so much in his life.” (40) While the change in perspective from “they looked” to “he read in their eyes” leaves open to question the accuracy of Bliakha’s observations, the fact that he perceives guilt, or at least “something more like guilt” in the eyes of his fellow villagers introduces a key theme of the story: collective culpability. Gubarev’s Sarcophagus creates a black-and-white version of the Chernobyl story with a clear distinction between victims and villains. Chief among the play’s villains is the Director of the power station. At the conclusion of the play, Bessmertny asks the doctors to transplant some
of his bone marrow into the Director in order to save his life. Bessmertny’s altruistic act stems from his sense of justice, not his sense of compassion: “He must live. He has no right to die along with them [the innocent victims of the accident]… I want to condemn him to life.” (41) While Gubarev paints a world where justice will be served once the guilty are identified and punished, Fedarenko’s story is colored by shades of gray. Fedarenko expands the categories of victim and villain and blurs the line between them. Writing several years after the explosion, Fedarenko is not interested in naming those who caused the accident. Instead, through repetition of words like “guilt” and “guiltily” the author paints a world of shared responsibility where everyone is capable both of victimizing others and of being victimized. Waiting for Bliakha to arrive, the old man feels “guiltily silent” before his wife because he has become so weak and ill that he needs the help of the village outcast to slaughter a hog. (42) For his part, “Bliakha, [felt] guilty the whole day and [saw] that he could not please the old lady.” (43)

Moreover, in contrast to Gubarev’s characters, who espouse scientific, technological, or bureaucratic views of the Chernobyl accident (thus the Physicist and the Investigator each try to answer the question “What happened?” in accordance with his profession), Fedarenko’s rural Belarusian characters “never believed in any Chernobyl disaster or radiation. […] One couldn’t believe in such nonsense.” (44) The Chernobyl tragedy is portrayed not in terms of technology gone wrong, but as an essentially human tragedy. Humans caused the misfortune and now must bear it. In a passage marked by free indirect discourse, the narrator explains why the old farmer and his wife do not believe in the “nonsense” of Chernobyl:

Radiation, which had been neither heard nor seen before by anyone, did not come by itself; it was something produced by people, directly related to them. It wasn’t radiation that drove people from their homes, invented the “zone” and put a fence around it; it wasn’t radiation that kept farmers from making hay and rejected their milk, cows, and pigs. All this was done by people, people like the old man and his wife. (45)

To the old man and his wife, the identity of the Chernobyl villains is unimportant. Humans caused the accident that spread so much radiation. We are all human. Therefore, each one of us shoulders part of the collective responsibility. Each one of us has wronged another.

The central illustration of the blurred line between villain and victim is the character of the young Russian soldier with “round blank eyes,” an outsider to the village. (46) While walking to the old man’s house, Bliakha encounters the Russian, who kicks him in the chest for no reason and then drives away. After Bliakha, the old man, and the wife slaughter and clean the hog, the Russian reappears at the farmer’s house. He threatens the old man’s wife and steals the pork from the house, only to be attacked in the yard by a pack of wild dogs, abandoned house pets...
now joined in a vicious pack. Although the thief has been torn to pieces by the vicious dogs, Bliakha recognizes him as his assailant, and returns the blow. This action, however, offers Bliakha no satisfaction. Instead, he feels remorse and even a sense of kinship, “as if the young man were his son.” (47) As he runs to the paramedic’s house to get aid for the Russian, Bliakha is killed by the dogs.

Two forces are at work in this story: the human force of community (represented by the village) and the elemental force of the wild dogs. The Chernobyl accident destroyed the first and, in so doing, also created the second. Overcome by pity for the young Russian, Bliakha tries to save him, and dies in the process. Helping others in the village gave Bliakha purpose and energy, but his eventual death seems more foolhardy than heroic. Bliakha is so hungry for human contact that he believes his good deeds will join him to his fellow man. In the end, his fellow man is powerless to save him from the forces of nature.

Svetlana Aleksievich’s *Voices from Chernobyl*

Because it includes multiple points of view, Aleksievich’s moving *Voices from Chernobyl: Chronicle of the Future* (originally published in Russian as “Chernobyl’skaia molitva: khronika budushega,” literally *Chernobyl Prayer: Chronicle of the Future*) is an excellent complement to Gubarev’s play, Sirota’s poetry, and Fedarenko’s short story. Aleksievich completed her book more than ten years after the accident at the Chernobyl nuclear power station. In contrast to works dating from the glasnost era, such as *Sarcophagus* or *Chernobyl: A Documentary Story*, *Voices from Chernobyl* is not concerned with uncovering the facts of the accident. It does not retrace the mistakes made before and after April 26, 1986, nor does it identify Chernobyl’s heroes and villains. Aleksievich’s book is more open-ended than earlier works about the Chernobyl accident, a trait the author herself recognizes: “I don’t feel like a chronicler of the past. It seems to me that I’m describing the future.” (48) To Aleksievich, Chernobyl and its aftermath portend future large-scale catastrophe.

*Voices from Chernobyl* explores more deeply than do the other works the theme of identity in the aftermath of the accident: what does it mean to be a Russian, Ukrainian, or Belarusian? How can a person identify her homeland as the Soviet Union if it has ceased to exist as a geopolitical entity? Is it not a contradiction that two different groups of people identify themselves as “Chernobylites” (*chernobyl’tsy*) in Aleksievich’s book? The term is used by evacuees from the afflicted lands who have been resettled in Minsk and Kiev and by refugees from wars in Chechnya and Tajikistan who have sought shelter in the vacant, poisoned lands of Belarus.

To write *Voices from Chernobyl*, Aleksievich conducted interviews in Belarus over the
course of three years, collecting the personal narratives of those whose lives were shaken by the Chernobyl catastrophe: medics, soldiers, members of the clean-up crew, evacuees, children, scholars, widows, and farmers. (49) Aleksievich takes the title *Chernobyl Prayer* (not preserved in this English translation) from one of her speakers, the widow of a liquidator: “I will whisper my Chernobyl prayer.” (50) The title itself illustrates how the book eschews a closed historical perspective. A prayer, after all, is an appeal for intervention or guidance in the present or future, not a history of what has taken place. Although the book is not modeled on a prayer in any liturgical sense, it is constructed from individual and group testimonies with headings that emphasize the human voice, such as “chorus,” “monologue,” or “a solitary human voice.” This alternation between individual and collective voices has an element of ritual. Moreover, through the act of telling their stories, Aleksievich’s speakers take part in a cultural ritual, becoming linked as “people of Chernobyl.”

Aleksievich expresses herself directly in a single, brief section, entitled “Interview by the Author with Herself about Missed History.” She explains her reasons for undertaking this project and also admits that this book is different from her previous works because of her personal link to Belarus: “My life is part of the event. I live here.” (51) By naming this section an interview rather than a monologue, Aleksievich emphasizes the lack of a dominant, authoritative voice in the book: even the author is just another informant to be interviewed. Aleksievich shares her authority as a writer with her interlocutors, so that each sample of collected speech has two subjects, to borrow Philipe Lejeune’s model: “He who, fleetingly, at the time of the questioning, remembers and speaks, and he who listens, constructs the memory, and integrates it into the universe of writing”. (52) Critic Lev Anninskii notes with irony the peculiar meaning of authorship in Aleksievich’s creative works as a whole: “From story to story the writer’s worldwide reputation grows, while 99 percent of her texts belong to other people.” (53)

Anninskii’s statistic notwithstanding, Aleksievich plays a crucial role in filtering and ordering the voices of others. For example, in the book’s opening and conclusion, the author frames the personal narratives with excerpts from published newspaper and encyclopedia reports about Belarus and the Chernobyl accident. The impersonal reports she cites, although informative, translate individual lives into collectivized social terms: “After Chernobyl the country [of Belarus] lost 485 villages and settlements: 70 of them are forever buried in the earth.” (54) Aleksievich thus conveys that the vast documentation of the Chernobyl catastrophe has not been translated into a greater understanding of the accident and its aftermath. The author moves from reported facts to human memory, giving voice to those behind the nameless statistics. As the writer once stated in a newspaper interview: “One must begin with the importance of an
individual human life.” (55) She presents not only the staggering totality of the accident, but also its individual cases.

Aleksievich builds a compelling strategy for relating the monstrosity of this terror, moving between statistics and personal narratives. The author juxtaposes the statistics with two related testimonies, each entitled in the original Russian “Odinokii chelovecheskii golos” or “A Solitary Human Voice” (Curiously, the translator of Voices from Chernobyl renders this single title as “A Solitary Human Voice” for the first testimony and as “A Lonely Human Voice” for the second.) The first voice belongs to Ludmila Ignatenko, the widow of firefighter Vasily Ignatenko, who was part of the unit that attacked the flames on the roof of the reactor in a frantic but ultimately successful attempt to prevent the fire from spreading. Ignatenko, along with thirty-one other firefighters, perished from acute radiation sickness soon after. The second solitary voice, which appears at the book’s end, is that of Valentina Panasevich, whose husband, sent to shut off electric service to evacuated villages, later died of cancer. The epithet “solitary” in this shared title reflects the young women’s widowhood, but also emphasizes individual human tragedy over anonymous statistics. By opening and concluding the personal narratives with these accounts, Aleksievich also combines two seemingly incongruous themes: Chernobyl and love. (56) Ignatenko, after all, begins her account with the provocative statement “I don’t know what to tell you about. Death or love? Or is it one and the same?” (57)

In addition to her role as the editor, Aleksievich appears in her book as the addressee; people not only entrust their stories to her, but also appeal to her with requests. At times, Aleksievich’s interlocutors express their disbelief and hesitation: “You’re going to write about this? This! I would not like people to know this about me.” (58) Others seem to privilege Aleksievich, entrusting her alone with their stories. A young refugee from Dushanbe admits: “I can’t talk about that. I’m expecting a baby, I’m pregnant. But I will tell you.” (59) In her role as the sympathetic listener, Aleksievich, even when not expressing herself directly, is able to create a literary persona of a trustworthy author-confidante, an agent of information and truth: “Tell everyone about my daughter,” pleads a mother identified as Larisa Z. “Write it.” (60)

Once told, narratives may take on an identity independent of the teller. One interlocutor—a woman by the name of Zinaida Kovalenka who returned alone to her abandoned village—talks about memory in terms not of personal remembrances, but of remembering for the sake of others: “I’ll remember it all for you” (emphasis added). (61) She concludes her story: “Well, dearie, have you understood my sorrow? You’ll tell it to people, and I may not even be here anymore.” (62)

As she seeks out these individual stories, however, Aleksievich recognizes the limitations of human memory. Using the word vospominaniia, which can refer to “memories” or more
literary “memoirs,” she says: “Memories are a delicate thing, capricious. It’s very difficult to detect reality, to extract it from chaos.” (63) Besides the frailty of human memory, Aleksievich is also concerned with how to record events that test the limits of language.

In her “Interview by the Author,” Aleksievich notes that she consciously decided to retain in the book’s final version a refrain she heard repeatedly from her interlocutors: “I cannot find the words to describe what I saw and felt.” (64) One of her interviewees expresses a lack of faith in language itself to describe the Chernobyl tragedy, questioning, “Is the world captured in words true? Words stand between man and his soul.” (65) The speakers express the singularity of their experiences as well as the impossibility of an adequate description. One of the liquidators testifies: “No one can speak to me in a way that I can answer. In my own language. No one understands where I’ve been. And I can’t talk about it.” (66) “It’s impossible to tell this! It shouldn’t be written!” Liudmila Ignatenko reiterates in her account. (67) Another woman, evacuated from Pripyat, laments that she will never be able to visit her grandmother’s gravesite: “I understood that I would never be able to visit my grandmother. I understood it. And where can you read about that? Where had that ever happened before?” (68) Neither removing nor explaining these repeated refutations of the adequacy of language, Aleksievich allows them to accumulate until they begin to annul themselves. Despite their protestations, Aleksievich’s interlocutors are not driven into silence. They manage to express themselves, often quite eloquently and poignantly.

In order to clarify their experiences of an unfamiliar or even catastrophic situation, Aleksievich’s interlocutors frequently share linguistic patterns and symbolic referents, demonstrating Kristin Langellier’s observation that “The very fact that experience is put in the shape of a narrative renders it subject to the desires and choices of the teller, to the constraints of the audience, and to the forces of narrative traditions.” (69) These allegedly unmediated first-person accounts simply cannot escape the influence of earlier models and so speakers’ expressions of their personal despair become paradigmatic.

One of Aleksievich’s observations both demonstrates and comments on the shift from literal to figurative language: “More than ten years have passed. Chernobyl has become a metaphor, a symbol. Even history.” (70) The author does not explain this metaphor or symbol, instead deferring to her speakers to define for themselves what Chernobyl has become. More significant than the meaning is the construction the author uses to express a shift or change: “to become someone/something” (in Russian: stat’ kem/chem). This mode of discourse is echoed in the language of several interlocutors, who attempt to describe not only their personal losses, but also the loss of traditional definitions and identities. The mother of a girl born with com-
pounded congenital defects laments: “I’m willing to let my daughter become a human guinea-pig, to experiment on like a rabbit or frog, if that will keep her alive.” (71)

Speakers repeat a related metaphorical construction to signal their view of the Chernobyl accident as a liminal event that swept away the familiar. Irradiated objects are repeatedly described as “not X, but Y” (ne ... a ...), or more emphatically, as “no longer X, but Y” (uzhe ne... a...). A hunter who witnessed the illegal removal of buildings from the radioactive zone recalls: “Even though they weren’t schools, or houses, or kindergartens anymore, but numbered objects for deactivation.” (72) A liquidator remembers testing a stove with the Geiger counter: “It’s no stove, it’s a small reactor.” (73) Marat Kokhanov, the chief engineer at the Institute of Nuclear Energy of the Belarussian Academy of Sciences uses this phrase three times in his narrative, describing meat, milk, and other foodstuffs as “not meat, [etc.] but radioactive waste.” (74) While Kokhanov’s use of this trope seems quite natural for a radiation specialist determining levels of contamination, the same phrase, when used to describe people, estranges and dehumanizes them. Ludmila Ignatenko recalls how the hospital staff informed her of her husband’s condition: “You must not forget: what you have here is no longer your husband, the man you love, but a radioactive object with a high density of contamination.” (75) Similarly, Ignatenko was warned by a nurse not to get too close to her husband: “He’s no longer human, he’s a reactor.” (76) Expanding the scope from objects to individuals to countries, Aleksieievich notes that people treat the nation of Belarus as if it were “no longer a country, but a Chernobyl laboratory.” (77) Throughout these testimonies, a common pattern begins to emerge as once-familiar objects, people, and countries slip from their literal meanings into figurative ones. Radioactivity is seen as a mysterious force having the power not only to transform objects on the molecular level, but also to change their very identities.

Comparisons and Overview

Because of its poignancy and because it describes the same time period presented in Sarcophagus, Ludmila Ignatenko’s testimony resonates with Gubarev’s play. Ignatenko describes in detail how she witnessed her husband’s descent toward death in the Moscow hospital where the Chernobyl firefighters were treated. She mentions by name Dr. Gale (represented in Gubarev’s play by Dr. Kyle) and Angelina Gusnova, the Russian surgeon who was the inspiration for the character of Lydia Ptitsyna. Some of the episodes recalled by Ignatenko are echoed in the play. For example, Ludmila’s husband paid a nurse in his ward to buy him three carnations, which he presented to his wife on May 9, Victory Day. (78) In the play, the Fireman does not have his wife nearby, but the young doctor Vera looks after him. At the beginning of act two scene two,
Anna Petrovna, a physician and research scientist, delivers to the Fireman “One red rose, as requested.” (79) Sadly, he dies before he can make his presentation to Vera, who finds him with “the rose [. . .] lying on his chest.” (80)

One place where the two accounts greatly differ is in the presence of the patients’ family members who are witnesses to their death. Ludmila Ignatenko relates that she was able to talk her way into the isolated ward where her husband lay dying of acute radiation poisoning. Although warning her of the danger and admonishing her neither to touch her husband nor to show too much emotion, Dr. Guskova grudgingly allowed Ludmila to see him. A much more rigid atmosphere is portrayed in Sarcophagus, which most likely reflected the institute’s official protocol if not its application. Bessmertny, for example, when asked about his family, exclaims: “I have no past. [. . .] I’m not aware of having a wife and family. My family is here, around me [. . .]. Beyond these walls there is nothing.” (81) Anna Petrovna explains Bessmertny’s outburst: “The only people admitted here are patients whose radiation dose exceeds the terminal level. [. . .] Does that sound cruel? On the contrary, it is humane. Our patients simply cannot meet their relatives because they cannot survive in close proximity to them.” (82)

The contrasts between the Chernobyl literature of Gubarev and Aleksevich illustrate the distinct ways that literature attempts to make sense of the tragedy. In contrast to Aleksievich’s collected testimonies, the dramatic space of Gubarev’s play is cut off spatially from the outside world. This deliberate literary device allows the playwright to focus on the views and emotions of a few characters. Moreover, Sarcophagus is set in a Moscow institute, at a geographic distance from the accident. This allows the playwright to concentrate on naming the guilty while ignoring the conditions still developing in the areas directly affected by the explosion: the evacuation of towns and villages, the long-term environmental degradation. Put another way, Gubarev’s play presents the Chernobyl explosion as an event with a clear beginning and end, whereas Aleksievich depicts it as a process, which continues to touch the lives of people in the afflicted regions years after the initial blast.

Aleksevich’s book is also a reply to the official Soviet view of Chernobyl, as “a victory, a story with an ending, and an ending that was triumphant.” (83) Voices from Chernobyl demonstrates how much about Chernobyl is still not known. One of her interlocutors, a university instructor in Belarus, observes: “I wondered why there was a silence about Chernobyl, why our writers wrote so little about it but kept writing about the war and the camps. [. . .] If we had been victorious in Chernobyl, there would be much more written and said about it. Or if we had understood it.” (84) What this passage implies is that to understand Chernobyl would
mean to have some victory over it. Even after so many years have passed and so many conferences, films, books, and works of art have been dedicated to the disaster, much remains unknown, and thus unconquered, because the story is not yet finished. The repercussions from Chernobyl will continue for generations to come.

Of the four authors surveyed, Gubarev’s writing is temporally the closest to the disaster, but psychologically the most distant. This psychological distance exists not only because the play is set away from the plant, in Moscow, but because the human society of Gubarev’s creation still functions according to the standards of the pre-Chernobyl world. Aleksievich portrays a world transformed by Chernobyl. For the speakers in Voices from Chernobyl, the tragedy of Chernobyl is not the death of innocent victims, but the horror of watching others die and of living in the aftermath. Assigning blame does not ease the suffering of people living in the afflicted lands.

In the end, these four distinct literary reactions to the Chernobyl disaster teach us something that volumes of scientific research leave out. Science can quantify the causes of the Chernobyl disaster and measure the extended effects of exposure to radiation, but Chernobyl is not simply a scientific or technological phenomenon. If nothing else, the image of liquidators without proper gear removing radioactive debris by hand should remind us of the limits of technology and that the Chernobyl disaster needs to be explained in humanistic, as well as scientific, terms. There is a vast human cost when technology fails. Literature, to borrow a phrase from Margaret Scanlan, faces up to the catastrophe, “measures its human consequences, and refuses to be consoled.” (85)

References


Endnotes


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57. Alexievich [Aleksievich], *Voices from Chernobyl: Chronicle of the Future*, 5.
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63. Aleksandrov, “Dorogoi gost’.”
64. Alexievich [Aleksievich], *Voices from Chernobyl: Chronicle of the Future*, 20.
65. Ibid., 55.
66. Ibid., 64.
67. Ibid., 10, 15. In the original Russian, this protest—“Eto nel’zia rasskazat’! Eto nel’zia napisat’!” (14, 20)—conveys a greater sense of an impossible (not merely undesirable) action. Ignatenko utters this identical formula twice in her narrative, while the translator of *Voices from Chernobyl* renders it as “I can’t say it! You can’t write it!” on page 10.
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71. Ibid., 70. [“Ia soglasna, chtoby moia devochka stala podopytnym liagushonkom, podopytnym krolikom, tol’ko by ona vyzhila” (78).]
72. Ibid., 83. [“Khotia eto uzhe ne shkola, ne dom i ne детский садik, a nomernye ob’ekty deaktivizatsii” (91-92).]
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Chapter Eight

RADIATION, RADIOACTIVITY, AND RADIOBIOLOGY: A PRIMER

Michael H. Patrick

Discussions of the physical health effects of the Chernobyl disaster are fundamentally about the immediate and long-term aftereffects of radioactivity and radiation: what the radiation did and is still doing. Before we can begin to sort through these effects, however, it is necessary to step back and ask a few questions about radioactivity: What is it? Where does it come from? How is it detected? How does it affect living things? How does it affect the entire environment? We seek here to provide some answers to these questions and, perhaps, help deal with the difficult question—"What might radioactivity do in the future?"—since many of the sociopolitical and psychological issues stemming from the Chernobyl catastrophe arise because of this uncertainty.

About Radiation

Simply put, radiation is a process by which energy is transmitted. By the end of the 19th century, physicists had recognized that energy could move through space in the form of vibrating, interdependent electric and magnetic fields that look like a wave passing by. For the physicists of
this period the spectrum of electromagnetic (EM) radiation included the visible, the ultraviolet (UV), and the infrared, but this spectrum was soon extended at both ends by the discovery of the very short wavelength X-rays and the very long wavelength radio waves.

By the turn of the century, however, it became evident that the wave properties of radiation could not explain how it interacted with matter. To make sense out of contradictory experimental observations required looking at the world in a brand new, revolutionary, way: It was postulated that EM radiation interacts with matter only in discrete bundles of energy, called photons. Thus was born quantum theory, and the bizarre notion that radiation behaves both as a wave and a particle. Nevertheless, the two, essentially antithetical, properties are related by this theory: a unit, or bundle (also known as a “quantum”) of energy in a photon is proportional to the frequency of the corresponding wave,

![THE ELECTROMAGNETIC SPECTRUM](image)

Figure 1.

When radiation interacts with matter, there are several possible outcomes depending on the energy of the radiation and the atomic or molecular composition of the material. First, the radiation can simply pass through the material; second, the radiation can be scattered (i.e., become diffused or dispersed) by the material; and third, the energy of the radiation can be absorbed by the atoms or molecules. When absorbed, these atoms or molecules now have more energy by an amount equal to that of the photon absorbed. Generally speaking, this is an unstable situation and somehow the energy must be dissipated. Depending on the energy, the possibilities can range from giving it up as heat to fragmenting chemical bonds. Very short wavelength radiation (e.g., X-rays) has considerable energy, enough to break chemical bonds, and constitutes what is called ionizing radiation. (1) Very long wavelength radiation, such as microwaves, interact with electrons too, and can cause chemical bonds to stretch and
bend; but photons with this energy come nowhere near being able to cause ionization and break the bonds.

All it takes to cause an effect is one photon; but the kind of effect is determined by the photon’s energy. The greater the energy of the radiation, the greater the chance to cause ionization. For low energy radiation, ionization will not occur regardless of how much radiation is present; no matter how long something is exposed to microwave radiation. For example, ionization would not occur and chemical bonds would not be broken (even though the thing would surely get quite hot!). Neither can infrared and visible electromagnetic radiation result in ionization. However, as we move into higher energy radiation, such as in the ultraviolet (UV) region, other things can start to happen. Although UV photons usually don’t have enough energy to remove an electron from an atom, (2) they do have enough energy to cause severe rearrangement of bonding electrons, a process called electron excitation. Sometimes the rearrangement is drastic enough that two atoms can no longer interact in a stable manner and seek out different bonding arrangements, thus changing the chemical makeup. Changes produced by non-ionizing radiation can have biological consequences, as discussed below.

Humans and other organisms in the biosphere are constantly exposed to energy across the electromagnetic spectrum. The biological response to this radiation depends on which molecules absorb what kind of radiation. Humans detect only a very small part of the electromagnetic spectrum. Our senses are tuned most acutely to wavelengths in the visible region, although we can feel the effects of wavelengths a bit longer than this, for example, the warming due to infrared radiation. So-called microwaves are at even longer wavelengths. Although our senses do not detect this microwave radiation directly, cellular molecules absorb it, increasing their vibrations. (3) Our senses are equally insensitive to radiation on the shorter wavelength side of the visual region, but that does not mean there are no biological effects. (4) Radiation in the ultraviolet region is absorbed by many of the molecules found in cells. Fortunately for life on earth, however, the upper stratospheric ozone layer filters out the highest UV energy (so-called UV-C), which is absorbed by DNA and can cause both mutagenic and lethal damage due to alteration of the molecule. Finally, absorption of photons in the very high energy end of the spectrum (e.g., X-rays) causes ionization of atoms in just about any type of molecule. Because of the central role of DNA and its uniqueness in cells, it is damage to this molecule that underlies the lethal, mutagenic, and carcinogenic effects of ionizing radiation.

The fact that we are constantly bombarded by this broad spectrum of electromagnetic energy suggests two things. First, that life, as we know it, is not necessarily incompatible with the spectrum of radiation we encounter. Second, that living systems have evolved mechanisms
to deal with potentially harmful effects of non-overwhelming amounts of radiation. We shall later return to both points.

Radioactivity and Nuclear Fission

Stable and Unstable Atomic Structures

Nature chooses the most stable arrangement of protons and neutrons for any given element, which leads to that form becoming the most abundant. But there are other arrangements possible, with either more or fewer neutrons than found in the most abundant form. Thus, for each element, we can have different isotopes: species of an element with the same number of protons and electrons but different numbers of neutrons. Some of these are stable, even though they may not be terribly abundant; others are unstable. Unstable isotopes have more energy than their stable counterparts; this excess energy is given up spontaneously in the process of becoming a stable isotope. The term used for this process is “decay.” During decay, the excess energy is emitted either in the form of electromagnetic radiation or nuclear particles. Collectively, these emissions are called “radioactivity” and the unstable isotope from whence they were emitted is called a “radioactive isotope” or “radionuclide.”

About Nuclear Fission

What would happen if a neutron could be added to a nucleus of a stable isotope? Chances are it would make it unstable. In the early 1930s, the neutron was observed experimentally, roughly a decade after Ernest Rutherford proposed its existence. A few years later, its effect on the nucleus of a uranium atom was investigated, resulting in an amazing, heretofore unknown, nuclear transformation: bombarding uranium with neutrons caused the nucleus to actually cleave into two or more large fragments with the release of an enormous amount of energy. This phenomenon was labeled “nuclear fission” and a new kind of energy was discovered: nuclear energy.

![Figure 2](image-url)
There are two important points to take away from this diagram. The first goes to the heart of using nuclear fission to either create energy to generate electricity or to make bombs. When the researchers experimentally measured and then tallied up the total mass before fission (protons + neutrons + electrons) and did the same after fission, they were astounded to find that the two tallies didn’t match---there was some mass missing. Where did the missing mass go? The answer is that it is part of what holds the nucleus together and is released as energy—a great deal of energy!! The second point is that fission of one uranium atom generates more neutrons (about 2.5 on the average), each of which could cause another uranium nucleus to undergo fission. Using the uranium isotope, U-235, Enrico Fermi was able to create conditions in which nuclear fission became a cascading chain reaction in which the entire amount of uranium was consumed, accompanied by the instantaneous release of enormous amounts of energy. Fermi had thus opened the door to the atomic bomb, and later, to the use of nuclear energy to produce electricity.

Characterizing Radioactive Isotopes

We generally classify radioactive isotopes on the basis of three properties: the kind of radiation they emit, the energy of the radiation, and how fast the isotope changes, or decays, to a more stable form.

Kinds of (Nuclear) Radiation

The radiation can be in the form of either particles or electromagnetic radiation. Radioactive particles include the very heavy, positively charged alpha (a) particle, which is essentially a high-energy helium nucleus, and the beta (b) particle, which is essentially an electron (although it can be positively as well as negatively charged). And finally, there are gamma (g) rays, which are not particles with mass; rather, they are very high-energy photons.

When radioactive hydrogen (tritium) decays, for example, it emits a beta particle and the resulting stable structure is a helium nucleus. When radioactive carbon decays, it, too, emits a beta particle; the result is the formation of a stable nitrogen nucleus.
Therefore, in radioactive decay—at least when particles are emitted—the resulting element actually changes into another, so, there is a bit of “alchemy” involved here. In the heavier radioactive elements, the whole process can be quite complicated and messy.

Decay of uranium-238, for example, must go through several transformations before a stable nucleus results. That means that the decay of this isotope gives rise to a whole series of isotopes, each of which is radioactive.
It should be noted that the decay of naturally occurring U-238 is quite different from the events associated with nuclear fission. U-238 undergoes spontaneous decay because it is an unstable isotope; it is not undergoing fission, so its decay is not the same as a chain reaction that produces enormous energies. It does, however, create daughter products that are radioactive and must decay as well. (One of these is radon, which is a gas and can pose health problems because it can become part of the air we breathe.) Nuclear fission that occurs in reactors or bombs is quite a different matter. Not only is there enormous energy released, but some 200 different isotopes representing 35 different elements result from the fission of U-235 atoms many of which are radioactive. Among these are cesium-137, iodine-131, and strontium-90, all of which have potentially serious, even lethal, consequences for living systems.

**Energy**

The unit of energy we are familiar with in dealing with the macroscopic world is the Joule. (8) But in the microscopic world of atoms and particles, the unit of energy is the electron volt, or eV. (9) Because of the equivalence of mass and energy, we can refer to the mass of a particle in terms of its energy equivalent, according to Einstein’s famous equation, $E = mc^2$. Thus, the mass of a proton is set at roughly 1 GeV.

The different kinds of radioactivity span a spectrum of energies. Moreover, the way each interacts with matter means that each will lose all its energy differently. Alpha particles, even though most energetic, lose their energy easily: a few millimeters of air are sufficient to dissipate their energy. Gamma rays, on the other hand, can pass through a great deal of matter before the energy is dissipated. And betas fall somewhere in between.
Rate of Decay

How fast a radioactive atom decays is a unique property of each radioisotope. Radioactive decay proceeds in an exponential manner; that is, the rate of the decay is proportional to the number of radioactive atoms remaining. Mathematically, this means it would take an infinite time for all the radioactive atoms to decay. Therefore, the unit that is used to measure and compare rates of decay is the “half-life,” the time necessary for half of the radioactive atoms in a sample to lose their excess energy through radioactive decay. (10)

Depending on the isotope, this half-life can take a few seconds to billions of years. By and large, we are concerned about radioactive isotopes that have long half-lives because they can remain radioactive for a very long time and thus pose a potential long-term threat to living systems.

The most familiar unit in the measurement of the amount of radioactivity present in a sample is called the “curie” (although, in the new International System of Units (SI), it is the Becquerel; a discussion of measurements and units applied to radiation and radioisotopes can be found in the Appendix). To give a general idea of the range of amounts of radioactivity with which we are dealing, consider that medical diagnostic tests use radioisotopes in microcurie (millionth of a curie) amounts, whereas therapeutic uses may be thousands or millions of times higher, at the level of millicuries or curie. In the case of Chernobyl, however, we’re talking about millions of curies released into the atmosphere.

Natural (Background) Radiation

As mentioned earlier, we are bathed in radiation and have been since life first emerged on the planet. This radiation is basically two-fold: cosmic radiation from space, highly energetic
atomic nuclei or components thereof that travel through space at close to the speed of light (11), and the radioactive isotopes present in the earth’s crust. These range from the uranium that is a component of several rock types (e.g., granite) and provides external exposure to beta particles and gamma rays to potassium isotope, potassium-40 ($^{40}$K) which is ubiquitous in nature and is an important electrolyte (i.e., KCl) in cells and therefore internally bombards us with beta particles and gamma rays. (12) But the risk from either is virtually immeasurable; and they are unavoidable.

**About Radiobiology**

As noted earlier, ionizing radiation kicks electrons out of the atom. These electrons, which now have some of the energy of the radiation, are themselves capable of interacting with matter and changing it. Moreover, left behind is an ionized atom which is chemically reactive. Just how much ionization the radiation causes as it courses through matter again depends on the kind of radiation and its energy: Alpha particles cause a great deal of ionization, but in a short path; gamma rays, on the other hand, ionize sparsely, but over a great distance.

![Figure 6](image.png)

Thus, alpha particles are said to have a high “linear energy transfer,” or LET, while gamma rays have a low LET. Any given radiation’s LET indicates how effectively it causes biological damage; high LET radiation has a higher *relative biological efficiency* (RBE; e.g., the RBE for a gamma photon is about the same as a beta particle; if this is set at 1.0, then an alpha particle has an RBE of about 20.) Because of its importance in radiobiology, more is said about LET in
The following flow diagram shows a simplified scheme to account for the biological effects of ionizing radiation. Once the energy is absorbed, causing ionization and excitation of additional molecules, chemical changes can take place. Since a living system—cell, organ, organism—is an incredibly ordered structure and an extremely complicated system of interacting events, there are components essential for a living system that can be compromised in either a spatial sense (e.g., disrupting a structure) or a temporal sense (e.g., disrupting the flow of information or energy). It is not terribly difficult, therefore, to imagine that anything as energetic as ionizing radiation can and will easily disrupt this fine-tuned system. Under the overall rubric of “biological changes,” we can have both random and directed somatic changes (acute and lethal or chronic and debilitating) as well as long-term genetic changes. (13)

![Flow Diagram](image)

**Figure 7**

*Units of Radiation and Radiobiological Effects*

The effect of ionizing radiation on living systems depends on the amount and kind of radiation. The term “amount” is often called the dose and actually means “how much ionization is produced.” This word “dose” is potentially confusing since it can refer either to the amount of ionization produced at a given site (e.g., the surface of a body) or the amount of energy actually deposited (e.g., in the whole body or a specific organ or tissue). When dose is applied to radiation effects in human, it has the latter meaning. This concept can be subdivided further by differentiating between *absorbed dose* (measured in grays: 1 Gy = 1J/kg tissue) and *effective dose*
(measured in sieverts, $1 \text{ Sv} = \# \text{ Gy} \times \text{other factors}$), which takes into account the kind of radiation—and its relative biological effectiveness—and other factors such as the type of tissue. Both units honor the individuals whose work paved the way to our current understanding. The appendix gives a brief discussion of how these units originated, their interconversions and some perspective on the question of “How much is too much?”

When humans or other organisms are exposed to large doses of ionizing radiation ($\geq 1 \text{ Sv}$), there is widespread damage due either to direct interaction with the radiation or to secondary reactions that produce biochemical lesions. Both can result in physiological changes that vary with the radiation dose and its duration as well as the rate at which the radiation is delivered (14) and how much of the body is exposed. Tissues vary in response to immediate radiation injury. Cells wear out and must be replaced. It was found early on that cells that undergo rapid replacement also have enhanced radiation sensitivity. Examples of tissues in which such cell “turnover” is rapid include lymphoid and marrow cells, gonadal cells, and intestinal and skin epithelial cells. These tissues are more radiosensitive than others.

Acute radiation exposure causes disruption of cell renewal systems and direct injury of other tissues, all resulting in clearly defined clinical syndromes involving cerebral, gastrointestinal, hematopoietic, and/or immune systems. Chronic, low level exposures have a different but nevertheless debilitating effect. The graph below shows recent estimates of the amount of radiation humans in the US absorb from both natural and anthropogenic sources. (15)

---

**Figure 8**

---

Annual Radiation Exposure (U.S.)

- Human Sources (0.6 mSv, 18%)
- Natural Sources (3.0 mSv, 82%)

- Medical
- Nuclear medicine
- Consumer products
- Other (defense reactors, etc.)
- Internal terrestrial
- Cosmic

---

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A few examples of dose-related effects of radiation on human health may help put things into perspective:

- chest x-ray: 0.3 mSv  
- gastric fluoroscopy: 4 mSV  
- one coast-to-coast airplane flight: 0.02 mSv  
- watching color TV: 0.02 mSv  
- sleeping with another person: 0.01 mSv  
- smoking cigarettes: ~ 3 mSv/yr  
- $^{40}$K in your body: ~ 0.4 mSv/yr  
- contribution from nuclear industry: < 0.01 mSv/yr  
- lowest dose at which a deleterious health effect has been observed: 200 mSv  
- recommended maximum annual industrial exposure: 20 mSv  
- dose to cause severe radiation sickness: ~ 1000 mSv  
- dose to cause 50% lethality among persons with acute symptoms: > 4500 mSv

For major radioactivity exposure, as in the case of the victims of Chernobyl and the Hiroshima and Nagasaki bombings, questions about the severity of the hazard cannot be answered definitively because we do not know precisely the amount and type of radiation that afflicted any particular area or group of people. We necessarily, then, only have estimates rather than direct measures of internal exposure, which can lead to controversy regarding doses and effects. Most of our understanding of the effects of radiation on humans comes from studies on the atomic bomb survivors. As thorough as these studies were and continue to be, they deal with the effects of an intense, brief exposure to radiation, which could well have very different consequences than the chronic, low-level contamination affecting the victims of Chernobyl. In addition to the problems on estimated dosages, there is the problem of correlating the dose with the effect on human health. (16)

Most of our estimates of the effects of very low exposure (i.e., <100mGy) are usually obtained by linear extrapolation from studies of higher doses (i.e., drawing a straight line through all the data points). This is an area of controversy; indeed, some argue that extremely low levels are actually beneficial. (17) Current standards for occupational and residential exposures to radiation are based on a linear, “no threshold” model that drives regulatory decisions and estimates of health risks. This model assumes that:
• risk is always proportional to dose, and
• there is no risk only when there is no dose

On the other hand, there is significant evidence to suggest that exposure to low doses or low dose rates of radiation are better described by a non-linear dose relationship. (See the appendix for a more detailed discussion.) This is from research on:

• cellular and DNA repair capabilities (see later discussion)
• cell communication and cooperation between neighboring cells
• the multi-step nature of cancer
• the long-term studies of human and animals at organismal, cellular and molecular levels
• radiation hormesis studies

Shown here is a hypothetical distribution of data through which lines could be drawn and extrapolated to support either model because of the lack of data for very small doses.

As a source of radiation, radioisotopes can be particularly pernicious because they often are atoms that are either part of the normal human metabolism or that can mimic the metabolic effects.

Moreover, they can deliver the radiation both externally and internally and, depending on how long the isotope remains in the body (18), possibly for a considerable period of time.

Below are listed a few of the isotopes that figured prominently in the Chernobyl disaster,
and continue to do so.

**Long-term isotopic contamination due to Chernobyl**

\[ ^{137}\text{Cs} \left(t_{1/2}\right) = 30 \text{ years}; \text{ b and g emission}\]  
\[ ^{131}\text{I} \left(t_{1/2}\right) = 8 \text{ days}; \text{ b and g emission}\]  
\[ ^{90}\text{Sr} \left(t_{1/2}\right) = 28.5 \text{ yrs}; \text{ b emission only}\]

**Strontium**

Sr is an alkaline earth metal and is a member of the same group of the Periodic Table as Ca and Mg. In the body, it mimics both of these metals by being absorbed by the same carrier systems and tends to localize in bone where it is incorporated into the bone’s structure and therefore can reside there for many years, resulting in bone being irradiated, causing bone cancer. Its analogy to Ca means that it is secreted in milk (e.g., from cows: drunk by children, it accumulates in their bones).

**Iodine**

Because I is a component of thyroxin, isotopic iodine will localize in the thyroid very quickly, irradiating the surrounding tissue, causing thyroid dysfunction and cancer. But since its half-life is so short, the major health effects developed among those who were in the immediate vicinity of the Chernobyl reactor accident where the incidence of thyroid cancer.

**Genetics and Radiation: Effects at the Level of DNA**

Over the years, scientists have concluded that a definite hierarchy of processes is involved in genetic effects. The blueprints for how to create a particular life form are contained in the cell’s DNA; that is, there is coded information to make tens of thousands of different proteins that, collectively, carry out the activities constituting what we call life. If the DNA is damaged, these proteins will be adversely affected and the process we call life can grind to a halt. Or, even if life doesn’t end, the genetic code can be changed sufficiently so that the proteins are altered in progeny cells and detrimental changes can occur down the line. It is in this way, roughly speaking, that radiation might have cancer-producing effects. (19)
A few of the ways DNA can be altered include:

- altering the bases—that part of the molecule that is the code, and/or
- the physical structure of the molecule can be compromised by breaking one or both strands that contain the linear sequence of coding bases, and/or
- the two strands could become, via chemical reactions between ionized parts, “glued” to each other and cannot unwind to undergo replication.

Any and all of these events are potentially serious; but unless the dose is large, cells generally don’t suffer the bad effects. The reason is that very early in evolutionary history living systems developed the ability to repair damage to DNA caused by various toxic agents. Indeed, this feature of cells is so ubiquitous that even simple viruses carry in their genes information that code for repair enzymes. The importance of this is underscored in more complicated life forms by the simultaneous occurrence of several different kinds of repair systems, all of which function to monitor the integrity of the structure that carries the blueprint for survival of the species. Damage to DNA can come about in various ways: externally in the form of radiation or chemical agents, internally in the form of reactive metabolic products and simply made during the copying of DNA during replication and cell division. (20) What this says is that the human genome is exceedingly resilient due largely to the plethora of error-correcting mechanisms. (21) In support of this is the relatively recently published results of analysis of Hiroshima A-bomb survivors and their offspring, which showed little, if any, “genetic load” in the children of survivors. This will undoubtedly be studied even more closely as a result of the completion of the Human...
Indeed, one of the problems in assessing radiation risk to humans based on experimentation with model systems, whether those be bacteria, fruit flies or mice, is trying to correlate a given biological effect—mutation, death, or other—with measurable physical/chemical changes in the DNA. In humans, only a small fraction (about 2% or so) of the entire genome codes for proteins. Looked at in one way, that is a pretty small target; on the other hand, we would also have to assume that the damage sustained in all the rest is inconsequential or silent. Until that assumption is studied explicitly, many scientists believe that no firm conclusion can be made on just how resilient the human genome, or any other genome for that matter, really is.

Closing Remarks

Radioisotopes and radiation have always been part of the entire universe and always will be. Humans did not invent radioactivity; they discovered it. All stars are immense nuclear reactors where hydrogen nuclei are fused together to create new nuclei with the release of an incredible amount of energy, along with particles—debris, if you will—of the many reactions at the subatomic level that go on in the core of stars. The gaseous and particulate debris spun out from stars to coalesce into solid planets and asteroids, each of which has built into it naturally occurring radioactive isotopes. The core of the earth, for example, is heated by an intense radioactive furnace that circulates molten metals, producing the magnetic field of the earth, our main protection from the massive number of various particles coming our way from the sun that would otherwise be lethal. But the truth of the matter is that our planet, its core and to some extent its surface, is radioactive, which means that life emerged, evolved and continues to thrive in the presence of energy that can readily destroy it.

As noted earlier, for example, potassium is ubiquitous in nature: it is an important electrolyte (as KCl) in cells and therefore part of every plant and animal. The abundant, stable isotope is $^{39}$K, but the unstable, radioactive $^{40}$K isotope is also present. Thus, every cell is being internally bombarded with beta particles and gamma rays emitted from $^{40}$K. Since this isotope is but a tiny fraction of the total potassium, the amount of radiation is not appreciable. But, it is there for life of an organism. It is not only the isotopes that make up our bodies, but also the isotopes normally present in our environment. People hiking over granite rocks expose themselves to the uranium radioactivity in granite (but hiking over limestone rocks will not result in this exposure since there is no uranium in these rocks).
All of this means that built into the fabric of our genes, and the genes of every organism in the biosphere, is the information needed to survive and thrive in a potentially hostile environment, including one in which radiation is present. This, however, should not blind us to the fact that these amazing systems have evolved over a period of time in which the potentially harmful background “noise” has remained relatively constant. But human activity has significantly increased the level of the noise; it is not at all clear at what point the ability to survive and thrive could be seriously compromised. Chernobyl is but one—if horrendous—example; and a warning.

**Resources and Bibliography**

The articles listed below give an accurate account of the problems and controversies about estimating risks to humans by ionizing radiation. This is applicable not only to the fallout from the Chernobyl disaster and to nuclear weapons testing, but also to natural background radiation due to uranium deposits and radon gas. Many are now quite old, which shows that this information has been well-known and available for a long time, and that current knowledge confirms and supports these earlier studies. Thus, they retain their value for those interested in reading about the fundamental science of radiation and radiation biology.

The articles are arranged in a chronological order, providing an interesting perspective on how the arguments have shifted over the years. For the teacher prepared to devote the effort to peruse these materials, it is an exceedingly valuable example to share with students about how science is done and what it can and cannot do. This is, perhaps, one of the most important points to drive home to students about science and technology since, in the end, we must make policy in the face of controversy, conflicting data and incomplete knowledge—not only for radiation hazards but for many other technologies, as well.


The BEIR III Controversy (*Biological Effects of Ionizing Radiation—A report of a committee established by the National Academy of Sciences-National Research Council*).

Articles by: Jacob Fabricant, Edward Radford, and Harold Rossi; *Radiation Research*, vol. 84, pp. 361-405 (1980).


“Academy Panel Raises Radiation Risk Estimate.” Eliot Marshall, *Science*, vol. 247, pp. 22-23 (1990) *(See also the letters to the editor in succeeding issues which respond to this article)*


In addition to these printed references, there are several web sites devoted to radiation, nuclear power, and to Chernobyl, in particular. Use of these key words in your browser will gain you access to this changing resource. Several of these sites are worth drawing attention to. One is the “Why Files,” (http://whyfiles.org/index.html) created by the National Institute for Science Education at the University of Wisconsin-Madison and funded by the National Science Foundation. Go to their archives and click on “Health”; the file “Radiation Reassessed” is excellent and has, itself, a rich source of both print and electronic references. Another is the Radiation and Health Physics Page developed by University of Michigan health physics students – the nation’s future radiation safety officers – who have packed the site with informative documents and links: the URL is: www.umich.edu/~radinfo. And then too, those interested in the terminology employed in this field might want to consult “The language of the nucleus, on-line edition: The world’s largest nuclear glossary.” URL: http://glossary.dataenabled.com

**Glossary of Terms**

**Alpha particle**: a large, positively-charged particle emitted by some radioactive atoms

**Beta particle**: a small particle emitted by some radioactive atoms that can have a negative or positive charge

**Curie**: a measure of the amount of radioactivity in a sample; 1 Ci = 3.7 x 10¹⁰ disintegrations/s

**Dose**: a term that can mean either the amount of radiation produced at a site or the amount of radiation energy absorbed by a sample

**Electromagnetic radiation**: a spectrum of energies which can be equally well described as either wave-like or particle-like in nature (e.g. gamma rays, X-rays, UV light, visible light, infrared radiation, microwave radiation, radio waves, etc.)

**eV**: electron-volt, a unit of energy used at the level of atoms and their components

**Gamma rays**: high-energy electromagnetic radiation emitted by many radioactive atoms

**Gray**: the SI equivalent of the rad; the amount of energy, in Joules, absorbed per g of sample (1 Gy = 1J/kg = 100 rads)

**Half-life**: a measure of the rate of radioactive decay; the time it takes for half of a given quantity of a radioactive isotope to decay to a stable nuclear configuration

**Intensity**: the rate at which energy strikes a surface: the amount of energy transmitted per unit area per unit time. (e.g. Joules per square meter per second, or J/m²/s)

**Ionizing radiation**: radiation with energy sufficient to knock electrons out of atoms

**Isotope**: different forms of a chemical element, each of which has the same number of protons but different number of neutrons

**LET**: linear energy transfer; a measure of the spatial capacity of a given kind of radiation to cause ionization along a linear path through matter

**Nuclear fission**: the induced fragmentation of an atomic nucleus resulting in production of daughter nuclei and neutrons with the release of a large amount of energy

**Rad**: a measure of the amount of radiation energy absorbed per g of sample (1 rad = 100 ergs/g sample ≈ 1r)

**Radiation**: a process by which energy is emitted or transmitted

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**Radiation hormesis:** a stimulatory or beneficial effect induced by low doses of radiation that cannot be predicted by extrapolation from the detrimental or lethal effects at high doses

**Radioactivity:** spontaneous emission of particles and/or electromagnetic radiation from the nuclei of unstable isotopes; synonymous with “radioactive decay”

**Radioactive isotope:** an unstable isotope of an element that emits radiation to achieve a more stable nuclear configuration

**RBE:** relative biological effectiveness; this is not a defined unit but an empirically determined number that gives a measure of how effective the radiation is in producing a given biological endpoint

**rem:** “roentgen equivalent man,” a measure of the amount of radiation energy absorbed per g of sample that takes into consideration the RBE of the radiation (q.v.); \( \# \text{rem} = \text{RBE} \times \#\text{rads} \)

**Roentgen:** a measure of the amount of radiation produced at a site (1r = 83 ergs/g air)

**Sievert:** the SI equivalent of the rem, a measure of the effective absorbed dose that takes into consideration the RBE of the radiation; \( \#\text{Sv} = \text{RBE} \times \#\text{Gy} \)
APPENDIX

I. On Measuring Radiation and Radioactivity

Confusion about units used to measure radiation effects arise for several reasons. One reason is because there are different properties of the radiation that must be known before a measurement or estimate can be made regarding the biological effect. Another reason is that units used early on in radiobiology have been replaced, but still persist. Finally, the actual biological effect can vary for different kinds of radiation, even though the amount of energy delivered is the same. Our purpose here is to try to sort these issues out, since these terms and units will be used throughout the different analyses of the Chernobyl event and its aftermath.

When the source of radiation is radioactivity, as it was in the case of the Chernobyl disaster, we need to know:

- **how much radioactivity has been released (# curies):** About 500 million Curies (500mCi) were released into the atmosphere from the Chernobyl reactor. This estimate is based on measurements taken at several different sites in Europe and the Soviet Union shortly after the explosion. That estimate does not tell the whole story, however, since some of the radioactive isotopes released had short half-lives (e.g., $^{131}$I; $t_{1/2} = 8$ d) and disappeared from the environment quickly. Yet, many of those living in the immediate environs who received a high initial dose later developed thyroid cancer because iodine concentrates in the gland. Other radioisotopes were relatively long-lived (e.g. $^{137}$C; $t_{1/2} = 30$ y) and are still present in the immediate environs. They will contaminate the food chain for at least a century longer (i.e., after 90 years, there will still be 12.5 percent of the original activity remaining). The point to keep in mind is that, in addition to knowing how much radioactivity was released, we also need to know the kinds of radioisotopes and how much of the biological effect is due to the radiation external to the body and how much is due to internal radiation because it was part of the air breathed, food eaten, water drunk, and/or from contaminated wounds.

- **how much radiation energy is delivered to tissues (# sieverts):** In principle, we could use any unit of energy, but historically the erg (corresponding to the old “cgs” system of units) was used. The first unit of dose was the roentgen (r); the formal definition is rather formidable in its detail and arcane numbers but suffice it to say
that 1 r corresponds to the absorption of 83 ergs per g of air.* However, tissues are not air, so a unit that corresponded to the energy deposited in tissues was needed: the rad. By definition, 1 rad = 100 ergs of energy deposited in 1 g of tissue (so it isn’t terribly different from the roentgen, which prompts some to say that 1 rad ≈ 1 r…but the error can be serious, depending on the situation!). With the conversion from the cgs to mks (or SI: International System of Units) system of units, where the Joule rather than the erg is the energy coin of the realm, the rad morphed into the “gray” (named for the one of the pioneers of radiation biology, H.W. Gray): 1 gray (or Gy) = 1 J energy absorbed per kg of tissue. A bit of arithmetic shows that, since there are 10^7 ergs/J, 1 Gy = 100 rads.

But this is not the end of the story. For those biological effects where LET makes a difference, the rad must be modified to take into account the “relative biological effectiveness,” or RBE, of different radiations (this is also called, “quality,” or “Q”) ** Thus was born the rem (roentgen-equivalent man): #rems = #rads x RBE. In the newer SI system of units, the rem has been supplanted with the Sievert (Sv), named in honor of the Swedish radiological physicist, Rolf Sievert. An equivalent (or sometimes called, effective) dose of 1 Sv (= 1 J/kg) is received when the actual absorbed dose of ionizing radiation has been multiplied by Q (a dimensionless quantity which is the same as RBE) and N (the product of any other dimensionless multiplying factors). An example of N is the so-called “tissue weighting factor,” which reflects the observed radiation sensitivity of different tissues or organs:

<table>
<thead>
<tr>
<th>Tissue or Organ</th>
<th>Tissue Weighting Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>whole body</td>
<td>1.00</td>
</tr>
<tr>
<td>gonads</td>
<td>0.20</td>
</tr>
<tr>
<td>bone marrow</td>
<td>0.12</td>
</tr>
<tr>
<td>colon</td>
<td>0.12</td>
</tr>
<tr>
<td>lung</td>
<td>0.12</td>
</tr>
<tr>
<td>stomach</td>
<td>0.12</td>
</tr>
<tr>
<td>bladder</td>
<td>0.05</td>
</tr>
<tr>
<td>breast</td>
<td>0.05</td>
</tr>
<tr>
<td>liver</td>
<td>0.05</td>
</tr>
<tr>
<td>esophagus</td>
<td>0.05</td>
</tr>
<tr>
<td>thyroid</td>
<td>0.05</td>
</tr>
<tr>
<td>skin</td>
<td>0.01</td>
</tr>
<tr>
<td>bone surface</td>
<td>0.01</td>
</tr>
<tr>
<td>remainder</td>
<td>0.05</td>
</tr>
</tbody>
</table>

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Summary of Radiation Dose Quantities and Units

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>OLD UNIT</th>
<th>NEW (SI) UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>absorbed dose (quantity)</td>
<td>rad</td>
<td>gray</td>
</tr>
<tr>
<td>equivalent:</td>
<td>1 rad = 100 ergs/g</td>
<td>1Gy = 1J/kg</td>
</tr>
<tr>
<td>derivatives:</td>
<td>mrad (0.001 rad)</td>
<td>mGy (0.001 Gy)</td>
</tr>
<tr>
<td>effective dose (unit)</td>
<td>rem (= #rads x Q x N)</td>
<td>sievert (= # Sv x Q x N)</td>
</tr>
<tr>
<td>equivalent</td>
<td>1 rem = 100 ergs/g</td>
<td>1 Sv = 1 J/kg</td>
</tr>
<tr>
<td>derivatives</td>
<td>mrem = 0.001 rem</td>
<td>1 mSv = 0.001 Sv</td>
</tr>
</tbody>
</table>

What does it mean?

To put this into perspective, consider the following argument:

A total body dose of around 4 Gy, if delivered rapidly enough, is sufficient to kill 50 percent of exposed humans over a period of days or weeks.

\[
1 \text{ Gy} = 1 \text{ J/kg} \quad 1 \text{ J} = 4.184 \text{ C} \quad 1 \text{ Gy} = 4.184 \text{ C/kg}
\]

Assume a “standard human” has a mass of 70 kg; if the LD\(_{50}@4\) Gy (whole body exposure), then this dose deposits in the standard human a total energy of:

\[
70 \text{ kg} \times 4 \text{ J/kg} = 280 \text{ J} = 280 \text{ J} \times 4.184 \text{ C/J} = 1,172 \text{ C}
\]

What does depositing 1172 calories mean in terms of heat energy? To answer that, let’s see how much heat it takes to warm a 12 oz. can of beer from refrigeration temperature to body temperature: 12 oz is approximately equal to 355 ml of beer.

The definition of a calorie is the amount of energy required to raise 1 g water (or 1 g beer @ 1 ml beer) 1°C (strictly speaking, going from a temperature of 14°C –15°C). So, to raise a 12 oz. can of beer from refrigerator temperature (assume 15°C) to body temperature (37°C) requires
\[355 \text{ ml} \times 1 \text{C/ml/degree} \times (37 - 15) \text{ degrees} = 7810 \text{ C}\]

Therefore, 4 Gy of deposited radiation energy in the body of a “standard human” is about \(\frac{1172}{7810} = 0.15\) or 15 percent of that required to warm a can of beer to body temperature.

What, then, makes this energy so potentially devastating? The answer is that while heat energy is distributed uniformly in all molecules, all of the energy of the radiation photon or particle is transferred to a few electrons in a relatively few, but critical, cellular molecules and sufficient to break chemical bonds.

**Effects of Massive Doses of Whole Body Radiation**

\(~100\text{ Gy} :\) **cerebrovascular** syndrome: severe nausea and vomiting within minutes; disorientation; loss of coordination; respiratory distress; diarrhea; convulsions; coma; death in >99% of victims within 30 – 50 hours.

\(~10\text{ Gy} :\) **gastrointestinal** syndrome: nausea; vomiting; prolonged intractable diarrhea; lethargy; dehydration; emaciation; >99% of victims die in about 9 days

\(3 – 8\text{ Gy} :\) **hematopoetic** syndrome: transient nausea (~ 1 day); thrombocytopenia, lymphocytopenia, granulocytopenia (during 1 – 3 or more weeks); then hair loss, multiple hemorrhages, bloody diarrhea, oral ulceration, chills, fever; 50 percent of victims die in roughly 3 weeks.

**Putting it into Perspective**

The following graph, based on data from the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), 2000, shows the average individual global radiation dose from

- nuclear explosions
- the Chernobyl accident
- commercial nuclear power plants

Combined, this amounts to about 0.4% of the natural dose of 2.2 mSv per year.

In areas of Belarus, Ukraine, and Russia that were highly contaminated by the Chernobyl
fallout, the average individual dose was actually much lower than that in regions with high natural radiation background. This is not intended, however, to minimize the persistent health problems, since the nature and persistence of the isotopes in the fallout are as important as their amount, as discussed in the text.

Note that the greatest human-induced contribution to radiation dose has been from x-ray diagnostics in medicine, which accounts for about 20 percent of the average natural radiation dose.

* This unit applies only to ionizing radiation due to photons (g-rays and x-rays).

** To be precise, we are talking about the difference between “quantities” --- which can be expressed in terms of basic SI units—and “units,” which is a selected reference of a quantity ---- a modified quantity, if you will. This difference is not as trivial as it may sound, since one can be traceable back to solid reference units of length, area, and time while the other is empirical because the modification factors must be experimentally determined and thus open to change or disagreement. Q, for example, is a dimensionless number determined experimentally for each type of radiation, ranging from 1 for g-rays and b-particles to 20 for a-particles. Quantities are determined in the Standards Laboratory for the Conference General des Poids et Measures, in Paris, which is responsible for the SI units. The International Committee on Radiation Units and Measurements recommends units to the Conference.
II. RADIATION HORMESIS VERSUS LINEAR NONTHRESHOLD HYPOTHESES

Kelly Clifton

University of Wisconsin-Madison

Radiation hormesis and the linear-nonthreshold hypothesis are of considerable interest to the radiation regulatory agencies and recently to the general public. Hormesis has been defined as a beneficial hormone-like stimulatory effect on homeostatic regulation brought about by exposure to low radiation doses (Kondo). The linear, nonthreshold hypothesis holds that there is no radiation dose below which there is not a risk of biological damage, and that such damage increases linearly in direct proportion to increasing radiation dose; i.e. if the dose is doubled or tripled, the damage will be doubled or tripled, and so on (BEIR VII). If the linear nonthreshold hypothesis is wholly true, there is likely to be a call for more stringent control of the use of a variety of radiation-based diagnostic and other medical procedures and reconsideration of the safety requirements for industrial uses of radiation. On the other hand if hormesis is wholly correct then those diagnostic procedures and industrial uses will require considerably less rethinking, and the beneficial effects of low dose radiation may later be exploited for the benefit of mankind.

So which, if either, of these hypotheses appears closest to the truth? Proponents of both have difficulties in developing unequivocal proof. Interestingly, proponents of both of these mutually exclusive hypotheses cite cancer incidence data from the Radiation Effects Research Foundation’s Life Span Study of the atomic bomb survivors of Hiroshima and Nagasaki, Japan, in support of their particular interpretations. Plots of some of these data including a radiation dose-solid nonleukemia cancer incidence response, a radiation dose-mortality incidence response and a radiation dose-leukemia incidence response, all have initial “dips” below the no-radiation control incidences. These dips in incidences at low radiation doses are interpreted as the results of hormesis by proponents of that hypothesis. Likewise, surveys of the health and mortality rates among inhabitants of some areas in Asia in which the “background radiation” doses from radionuclides in the ground and water plus solar radiation is two to four times the background radiation doses of most other “control” areas have suggested lower frequencies of cancer including leukemia and in some cases somewhat longer life-spans among those in the high background areas than among those in “normal” background areas.

In contrast, the “dips” in cancer incidences among the Japanese A-bomb survivors who were exposed to radiation doses of about 10 mSv or less are interpreted by linear nonthreshold
proponents as being within expected statistical variations around linear nonthreshold-calculated curves, may in part be attributable to the way the data were subgrouped for analysis, and generally are matched by “blips” above the linearly-calculated cancer incidence values after somewhat higher or lower radiation doses.

The beneficial effects of living in high background radiation areas attributed to hormesis are usually very small, frequently are not subjected to statistical evaluation, and often appear to be within expected statistical variations. Also, the data are often collected by agencies other than the investigators themselves and are of questionable dependability. Other possible causes of differences between the groups living in the high and low background radiation areas are often not considered. Poor evaluation of the populations is frequently true of such survey-based studies.

As to the linear nonthreshold hypothesis, the incidence of leukemia does not increase linearly with radiation dose. Rather, a plot of the leukemia incidence against dose progressively curves more steeply upward with each incremental increase in radiation dose; i.e., if the dose is doubled or tripled, the leukemia incidence is more than doubled or more than tripled, respectively. Hence mathematical models other than the linear nonthreshold model “fit” the radiation dose-leukemia response data better.

Analyses that apply the linear nonthreshold model to solid cancers in groups comprised of different ages at the time of exposure can be misinterpreted unless all dose groups contain the same mixtures and proportions of ages. For example, breast cancer is far more common per unit radiation dose among female A-bomb survivors who were radiation exposed when infants than among those who were irradiated when adult. Indeed there is virtually no increase in breast cancer risk among those irradiated when about 45 years of age or older. Age at exposure is a very important factor in determination of many responses to radiation. Also in its purest form, the linear nonthreshold hypothesis does not take into account the fact that the biomedical damage produced by a radiation dose that is given rapidly in a single exposure is greater than the damage produced by the same total dose either given at a very low dose rate over a long period of time or the same total dose divided into small doses delivered at intervals of time.

What can be concluded about these two hypotheses? The linear nonthreshold model of radiation dose effects will continue to be helpful in analyses of many but not all radiation dose-effect relationships. One should be aware that a good statistical fit to a mathematical model does not alone constitute proof of the validity of a mechanistic hypothesis. As to hormesis, it will be interesting to see whether further investigation will show that small radiation doses consistently reduce the incidence of cancer and other ravages of age. It will require much more
research to demonstrate conclusively that hormesis \textit{per se} is a common and controllable phenomenon.

Finally, it may well be that if the linear nonthreshold hypothesis holds true in the 10 mSv range and lower, the risks to the individual will be so dwarfed by other causes of morbidity and mortality as to be negligible. Of hormesis, much the same may be said. The benefits expected may be so small as to make hormesis unattractive to apply.

\section*{Resources}


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\section*{Acknowledgements}

My thanks to my colleagues, Drs. Paul DeLuca, Doug Arion, Kelly Clifton, Eric Hagedorn, and to Mr. Dean Dolence (physics and biology teacher at Rufus King High School, Milwaukee) for their reading of the manuscript and suggestions for its improvement. Figure 1 was reproduced from “Chemistry” by Raymond Chang, 6th Ed., McGraw-Hill, with permission of the publisher. Figures, 3, 4, 5 were reproduced from “The Extraordinary Chemistry of Ordinary Things” by Carl Synder,(1992) and used by permission of the publisher, John Wiley and Sons.

\section*{Endnotes}

1. It is called “ionizing” because the photon has enough energy to knock an electron out of an atom, creating a positively charged ion. Since a chemical bond in a molecule involves mutual interaction of electrons from two of its atoms, ionization breaks the bond.

2. This statement is a bit dicey, but to clarify it would require going into how UV and X-ray photons are generated. Suffice it to say that there is overlap in energies between them, so that very energetic UV photons can indeed cause ionization. But photons in the so-called UV A, UV B, and UV C regions are non-ionizing.

3. Increased vibrations means increased heat energy. At sufficiently high intensity (e.g. microwave oven), this heating will destroy cells.
4. Most people, for example, have experienced the effect of UV A and B radiation in the form of tanning or sunburn.

5. This relates to the equivalence of mass and energy, as formulated by Einstein and discussed later.

6. Although many heavy nuclei can be made to undergo fission, including uranium-238, only the fission of naturally-occurring uranium-235 and of the artificial isotope, plutonium-239 has any practical importance. Both U-235 and U-238 occur naturally in ore called “pitchblende.” More than 99 percent is U-238; but U-235 undergoes fission much more efficiently. Thus the problem in making fissionable uranium is to enrich the ratio, U-235/U-238.

7. To be more precise, for an unstable atom decaying by β-emission, there are usually γ rays of one or more different energies emitted as well since the new nucleus is in an unstable state after particle ejection. The remaining particles readjust themselves to achieve a lowest-energy state and in so doing, emit one or more γ rays.

8. This is the unit of energy in the International System (SI) of Units. It replaced calorie, although this, and other units, are still used. One calorie equals 4.184 Joules.

9. Or, because we are dealing with tremendous amounts of energy, millions (MeV) or billions (GeV) of electron volts.

10. Like many processes in nature, radioactive decay is mathematically described as exponential. Suppose you start out with 100 radioactive atoms that decay such that after 1 second, there are 50 left. After 2 s, there would be 25, after 3 s, 12.5, and so on. How long will it take to get to zero? An infinite amount of time, as we learned a long time ago from Xeno’s paradox. So, since the time for radioactive decay completely cannot be measured, the next best thing is to ask: how long will it take for half of them to decay....which can be measured. This is the basis for “half-life.”

11. Cosmic radiation is a collection of many different types of radiation from many different types of sources, ranging from microwave radiation to neutrinos to high energy charged particles. The photons either have insufficient energy to cause harm or simply pass through without doing harm. The charged particles that do reach the earth generally are rendered harmless of interaction with the earth’s magnetic field and atmosphere.

12. From the known abundance of ⁴⁰K and its rate of disintegration, along with the concentration of potassium in the body, it is simple to calculate that a person weighing 105 lbs suffers some 20 million burst of ionizing radiation per hour due to radioisotopic potassium in the body. It is interesting to note that there are some plants that concentrate potassium, one being coffee beans. So, drinking coffee increases your “radioactive load.”...apparently without harm.

13. Somatic refers to all cells except germ (egg and sperm) cells. “Acute” and “chronic” are terms used to differentiate between an immediate, usually intense or severe, effect that occurs within hours to weeks (e.g. vomiting to death), and one that persists for a longer period of time and/or becomes manifest only after a period of time (e.g. cancer). This is an arbitrary way to sort out biological effects. An equally suitable way would be to distinguish between local and systemic damage.
14. A single rapidly delivered dose of radiation can be fatal, but the same dose delivered over a long period of time may be tolerated with little effect. (Just as you could take a bottle of aspirin over a lifetime with no ill effects, taking a whole bottle at one time can kill you!)

15. Taken from a report by the National Institutes of Health on the Biological Effects of Low Dose Radiation.

16. For example, according to reports summarized in a recent Science article (vol. 2599, 01/03/03, p.44), the average effective dose of radiation to adults evacuated from the 30 km zone around the Chernobyl plant in the Ukraine is estimated at 0.045 Sv (derived from the estimates given for ingestion of 0.005 Sv, inhalation of 0.025 Sv and external exposure of 0.015 Sv). In contrast, based on chromosome aberration counts in children evacuated from the Byelorussian exclusion zone, people in that region received an estimated average effective dose of between 0.1 and 0.4 Sv.

17. This is referred to as radiation hormesis (from the Greek, hormaen: to excite). According to this argument, radiation, like alcohol and caffeine, can have mild stimulating effects at low doses even though high doses can be detrimental or even lethal. First described in the 1940s for the effect of a fungicide on fungal growth, it was described for radiation effects in the 1950s. In its most general form, hormesis refers to a stimulatory or beneficial effect induced by low doses of an agent that cannot be predicted by extrapolation from the detrimental or lethal effects at high doses of the same agent. The concept of radiation hormesis is applied to physiological benefits from low LET radiation in the range of 1-50cGy total absorbed dose. The mechanism underlying radiation hormesis is not clear, but there are several reasonable and testable hypotheses. The concept would seem to argue strongly against the “linear-no threshold (LNT)” theory.

18. It is therefore necessary to consider not only the physical half-life of the isotope, but the biological half-life, as well. That is, it is necessary to know the rate at which a compound containing an isotope is eliminated from the body by normal physiological processes.

19. At the risk of muddying the waters, it should be noted that heritable alterations can occur in which the DNA sequence is not altered nor are the chains broken; that is, they are not mutational in nature. These are called “epigenetic effects.” Adding and removing chemical (i.e. methyl) groups on certain bases is an example, since the degree of methylation appears to be correlated with increased gene transcriptional activity (i.e. gene expression). There is increasing evidence that epigenetic effects may play important roles in radiation carcinogenesis by altering gene expression in somatic cells. The mechanisms to account for the observed phenomenon are still unclear; suffice it to say that the complete picture regarding genetic stability is still not completely understood. It does not, however, seriously affect the basic views discussed here.

20. Faulty repair has been implicated in the development of cancers.

21. As compelling as this argument is, some scientists believe it is blown out of proportion, citing studies that show significant damage occurring in cells that had sufficient time to repair. They also argue that not only do repair processes fail, they can themselves be damaged and cause the formation of faulty proteins, which can provide serious problems for cells (see, for example, Dr. John Gofman’s web site www.ratical.com/radiation/CNR/)
22.Interestingly, it was, among other things, a call to determine just how resilient the human genome is to agents such as radiation, made in the 1970s by Renato Dulbecco in an editorial in *Science*, that prompted the Department of Defense to propose funding an effort to determine the complete sequence of the human genome. It was only later that this was joined— and essentially taken over—by the National Institutes of Health under the rubric Human Genome Project.
Chapter Nine

THE BIOMEDICAL CONSEQUENCES OF THE
CHERNOBYL REACTOR ACCIDENT

Kelly H. Clifton

Kelly F. Clifton is Emeritus Professor of Human Ecology in the University of Wisconsin-Madison Medical School. His research for many years has dealt with the cells in the origin of radiation-induced breast and thyroid cancers. He served for over two years as a member of the Board of Directors of the Radiation Effects Research Foundation in Hiroshima and Nagasaki and on a variety of national government and non-governmental advisory bodies.

The fires in the core of Chernobyl Reactor No.4 and the explosions of superheated steam and flammable gases resulted in the release of about 50 million curies of radionuclides (radioactive atoms) into the atmosphere. These radionuclides were spewed out for ten days, contaminating the reactor site and surrounding areas in Ukraine, Belarus and Russia with radioactive fallout. Much smaller measurable levels of radionuclides were carried by the wind as far as the Arctic, Atlantic, and Mediterranean shores and Asia Minor.

The people afflicted by the ionizing radiation include those who received radiation doses sufficient to cause permanent debility and death, children who developed cancer, and also individuals with an increased susceptibility to several types of cancer and/or non-cancerous diseases. Many among the radiation-exposed groups are depressed by their belief that they might later develop radiation-related medical problems, and quite a few of them are also concerned that their offspring may carry radiation-related deleterious mutant genes.

The reports of the consequences of the Chernobyl catastrophe show how extreme can be the conclusions drawn about the biomedical effects of ionizing radiation. If we are to understand these extreme views adequately, we must appreciate the biological, physical and technical factors that can affect the validity of the judgments made about the causes of the biological
harm experienced by the accident’s victims. And this understanding requires an evaluation of a good many matters: the estimates that have been made of the cumulative radiation doses and the time patterns of these dose deliveries, the biological susceptibilities, and the relationships between the radiation dose received and the biomedical response that occurs. We must also assess the adequacy of the comparisons that have been made between with the consequences of the Chernobyl catastrophe and the biomedical effects in other radiation-exposed populations. And not least of all, we must also appreciate the concept of probability in risk estimation.

For simplicity’s sake, the term radiation will be used throughout this chapter to mean ionizing radiation. All radiation doses are expressed in Sieverts, or milliSieverts, measures of energy absorbed from ionizing radiation. As Patrick’s chapter in this volume also indicates, one Sievert equals one Joule of radiant energy absorbed per Kilogram of body mass, abbreviated 1 Sv. One milliSievert = 10^{-3} \text{ Sv} = 1.0 \text{ mSv}.

The Emergency Workers

Acute Radiation Syndrome (ARS) and Deaths

Six hundred reactor staff and emergency personnel were at the burning reactor site by 8:00 a.m. after the explosions and the outbreak of fire. These people were soon supplemented by about 220 recruits from outside the reactor area who joined in firefighting, decontamination, and the construction of the concrete “sarcophagus” around the reactor ruins. The approximately 820 individuals, herein termed “emergency workers,” were exposed to both the highest total-body radiation doses and the highest radiation dose rates of all the Chernobyl accident-related groups. About 713, or 87 percent, of the emergency workers received 0.5 Sv (500 mSv) or more of high-energy penetrating gamma rays from radionuclides released from the burning core. In addition, a significant number of them also received cutaneous burns from other radionuclides that adhered to their clothing and produced weak radiation that was absorbed primarily in the skin. In the worst cases, the estimated local radiation doses to the skin may have been as high as 400-500 Sv! For comparison, on the average, Americans are exposed to cumulative total-body doses of about 3 mSv per year of natural background radiation, and an additional 0.6 mSv or so from man-made sources and medical procedures.

Measurements of $^{131}\text{I}$ radiation to the thyroid glands were made on 208 emergency workers. Three percent of them had estimated thyroid doses of between 16 to about 23 Sv, and 15 percent, 1.2 to 13 Sv. If these figures are representative of all 820 workers, approximately 25 of
them would fall in the highest thyroid dose group, with about 123 others receiving the next highest dosage.

The first death from the accident was that of a badly burned man who expired on the way to the first aid station at the site soon after the first explosion. A second emergency worker apparently died near the reactor core ruins, although a body was not recovered. Including these two deaths, a total of 30 of the emergency workers suffered acute deaths.

During the first ten or so days, about 30 percent of the 820 emergency workers exhibited one or more symptoms of Acute Radiation Syndrome (ARS). Diagnoses of ARS were confirmed in 134 hospitalized cases, i.e., in about 16 percent of the emergency workers (Table 1). Cutaneous radiation burns were also found in 54 (40 percent) of the hospitalized workers.

What were the signs and symptoms that supported diagnoses of ARS? Firstly, of course, the workers were known to have been exposed to significant doses of ionizing radiation from the burning reactor core. Secondly, observations of previous radiation accident victims and irradiated experimental animals showed that ARS characteristically follows a three phase course. The first phase is associated with toxins released by damaged cells and transitory disruption of physiological integration. In humans it is accompanied by nausea and vomiting coupled with headache and fever. Its time of onset is quicker the greater the radiation dose. Among the emergency workers who received the highest radiation doses the first ARS phase began within a few minutes after radiation exposure, whereas the onset of the first ARS phase was more than two hours after exposure among the lowest dose group (Table 1).

The first ARS phase usually subsides within a few hours. Persistence of symptoms for 24 hours suggests that the radiation dose may be lethal. During the first and second phases, blood counts show a progressive decrease in the circulating lymphocytes, a white blood cell (WBC) type. Lymphocytes in the blood stream are sensitive to killing by radiation. The rate and level of decrease in circulating lymphocytes is proportional to the radiation dose, thereby providing important information in dose estimation and confirmation.

The second phase lasted for several weeks among patients with mild ARS and was progressively shorter among those with higher doses. During this period, exposed individuals typically feel relatively well; however, blood cell counts reveal progressive decreases in all types of circulating WBCs including the lymphocytes. WBCs play essential roles in combating disease organisms and toxins. The circulating WBCs other than lymphocytes are relatively resistant to killing by radiation; however, none of the circulating WBC types are able to replenish their own cell numbers when the mature functional cells die from the usual wear and tear. Circulating WBC populations are maintained by proliferation and differentiation by stem cells and their
progeny in the bone marrow and lymph nodes. Radiation inhibits this proliferation and kills the
stem cells. Hence, in ARS patients the circulating WBCs reach their life spans and die, and the
irradiated bone marrow stem cells are unable to replace them. The numbers of circulating plate-
lets that are essential for blood clotting also decrease from lack of replacement from their dam-
aged marrow stem cells. Similarly, the functional populations of epithelial cells that form the
outer layers of skin and the inner linings of the oral cavity, intestinal tract, and trachea are them-
selves relatively radioresistant but are also dependent on replacement from their radiation-
sensitive stem cell banks.

In the three groups of Chernobyl personnel exposed to the highest radiation doses (Table
1), the third climax phase developed when the circulating WBCs and platelet levels and the
epithelial linings of the intestinal and tracheal tracts were inadequate to maintain health. Epithel-
ial lining replacement failure led to ulcers (areas devoid of protective linings) in the oral cavity,
intestinal tract, and trachea, making eating and drinking difficult. Reduced blood clot formation
due to platelet deficiency resulted in localized hemorrhages beneath internal organ capsules and
in the skin, so there was increased bruising. Intestinal ulcers also allowed the leakage of unclot-
ted blood and body fluids into the intestinal lumen causing bloody diarrhea and salt and fluid
imbalance. Ulcers were also ports of entry for microorganisms from the intestinal lumina into
the tissues and blood streams; the reduction in WBC numbers allowed such invaders to prolifer-
ate and infect. In the typical sequence of changes the ARS climax phase is accompanied by high
fever and severe malaise, with its severity being greater, and its time of appearance being
sooner, the larger the radiation dose. The climax phase in the Chernobyl victims began close
after the first phase in high-dose, very severe ARS patients, and after days to weeks in the se-
vere and moderate, middle dose patient groups. In the lowest dose group the marrow and
epithelial stem cells were not sufficiently damaged to cause a full-blown ARS climax. Some
suffered transient periods of malaise four or more weeks after exposure.

Of the 134 hospitalized ARS patients, 28 (21 percent) died. Twenty of the 21 patients in the
highest dose, very severe ARS group died, as did seven of the 22 patients in the next highest
dose, severe ARS group (Table 1). Sixteen of the ARS patients who died also had severe cuta-
neous burns that may have hastened their deaths, but the bone marrow suppression and gastro-
intestinal ulcerations would likely have been lethal even in the absence of such burns.
Table 1


<table>
<thead>
<tr>
<th>ARS Degree</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
<th>Very Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dose, Sv:</td>
<td>0.8-2.1</td>
<td>2.2-4.1</td>
<td>4.2-6.4</td>
<td>6.5-16</td>
</tr>
<tr>
<td>No. workers:</td>
<td>41</td>
<td>50</td>
<td>22</td>
<td>21</td>
</tr>
<tr>
<td>Percent all 134:</td>
<td>31%</td>
<td>37%</td>
<td>16%</td>
<td>16%</td>
</tr>
<tr>
<td>No. died:</td>
<td>0</td>
<td>1</td>
<td>7</td>
<td>20</td>
</tr>
<tr>
<td>Percent of group:</td>
<td>0%</td>
<td>2%</td>
<td>32%</td>
<td>95%</td>
</tr>
</tbody>
</table>

The emergency workers, although the smallest adult group discussed herein, are the best documented. The nature of their radiation exposures, and the apparent radiation dose-dependence of the sequence of symptoms and signs in those workers who became ill and those who died, are all consistent with experience with other known heavily irradiated smaller groups. Although there remain questions as to the accuracy of individual radiation dose estimates due in large part to the scarcity of personnel radiation dosimeters (individual radiation dose measuring devices) at the accident site, the assigned dose estimates of those who were hospitalized are consistent both within and between groups with the observed courses of their illnesses. These observations leave little room to doubt that the ARS and cutaneous burns many of the emergency workers suffered, and the deaths among them, were the results of their exposures to ionizing radiation released by the Chernobyl reactor disaster.

**Intermediate Morbidity and Mortality**

Twelve emergency workers who survived hospitalization for ARS and who also had severe radiation burns were examined three to four years after the disaster. Eight of them had cutaneous fibrosis and six had skin ulcers in burned areas, the two most disabling burn sequellae. Fortunately, fibrosis is now treatable. Untreated progressive fibrosis often leads to painful joint im-
mobility and to skin ulcers, although ulcers may also develop in the absence of fibrosis. Radiation-induced ulcers are painful, rarely heal, commonly expand and often are the sites of debilitating infections and skin cancers. Amputation of limbs is sometimes done to stop ulcer expansion and halt or prevent cancers and infections. Skin cancer latency, the period from the radiation-related “initiation” of the multi-step cancer development process until the disease is diagnosable, is usually longer than four years. Thus, cancers were not expected so soon after exposure.

Eleven additional deaths occurred in the years from 1987 to 1998 among the emergency workers who had been hospitalized for ARS. Two who had been in the “severe ARS” group died seven and nine years after the accident from myeloblastic syndrome, a failure of the bone marrow to produce enough blood cells to support life. A third who had survived “moderate ARS” died 12 years after the accident with acute myeloid leukemia, a hemopoietic cancer that arises in bone marrow.

Although increased frequencies of both of these bone marrow conditions have occurred in some other irradiated populations, they also are seen in the absence of radiation exposure. No “radiation fingerprint” is as yet known, i.e., there is no way to distinguish a single case of radiation-caused myeloblastic syndrome or of myeloid leukemia from that arising in persons with no history of radiation exposure, and we cannot unequivocally say whether these three cases of lethal marrow conditions came about because of radiation exposures. These instances alone are examples of “anecdotal” data that are not useful in establishing radiation causality of illnesses or mortality.

Given that more than 85 percent of the emergency workers received total-body radiation doses of about or greater than 0.5 Sv, the threshold dose that will induce ARS in some individuals, and that many of these persons also had cutaneous radiation burns, it is very likely that they shall continue to suffer both increased risks of cancers and, to a lesser extent, other medical disorders to be discussed below. In addition, it is very likely that the high 131I thyroid doses may lead to local thyroid fibrosis, inflammatory disease, and hormone deficiency, as well as thyroid nodule formation and perhaps cancer. They may also have increased problems with hyperparathyroidism and calcium balance. All of them should receive medical surveillance, and those who were burned should be treated for fibrosis, ulcers, and burn-associated skin cancers. The emergency worker group is at greatest risk of continued and/or delayed biomedical consequences.
The Evacuees and Inhabitants

Total-Body Radiation Exposures

About 36 hours after the first explosion, evacuation of the contaminated areas began, starting with Pripyat, a Ukrainian town 3 km from the accident site, where reactor staff families lived. All of the people residing in the area 30 km in all directions from the ruined reactor were then also required to leave their homes so that the entire 30 km zone was cleared of inhabitants within two weeks. (This area is at times referred to as the “exclusion zone” in other chapters of this volume.) During the next four months, other residents of Belarus, Ukraine and Russia who lived in regions heavily contaminated with fallout radioactivity were similarly resettled. These resettled families, termed evacuees herein, totaled about 116,000 people.

About three percent of the then European U.S.S.R. was contaminated with initial $^{137}$Cs depositions greater than 1 Ci km$^{-2}$. Areas within these CRs (contaminated regions) that had more than 15 Ci km$^{-2}$ $^{137}$Cs were designated as ASCs (areas of strict control) in which remedial actions were taken. About 5,200,000 people who continued to live in CRs, including ASCs, were exposed to very much lower dose rates than were the evacuees; they are here termed inhabitants.

Initially, the main sources of radiation to the evacuees and inhabitants were $^{131}$I, $^{137}$Cs and $^{134}$Cs, with half-lives of 8 days, 30 years, and 2 years, respectively. As described below, $^{131}$I is unique because of the significant role of iodine in metabolism. As the radionuclides decayed and migrated, within a year $^{137}$Cs was the predominant source of external total-body radiation exposure in the CRs. The smaller amount of $^{134}$Cs initially present and its relatively short half-life reduced its importance. Food contamination by $^{90}$Sr and inhalation of $^{239}$Pu, $^{240}$Pu and $^{241}$Am were minor contributors to the total doses.

Radiation doses to the evacuees from the 30 km Exclusion Zone were estimated from multiple radiation measurements and $^{137}$Cs determinations throughout the zone and from about 50,000 completed questionnaires asking the evacuees about their locations and activities in the period from the first explosion until their departure from the contaminated region. The mean estimated total-body radiation doses to the evacuees from Ukraine and Belarus were approximately 17 mSv and 31 mSv, respectively. Cutaneous doses were estimated to be 3 to 4 times greater. However, small numbers of Belarusian evacuees received total-body doses greater than 400 mSv. These doses were delivered primarily during the evacuees’ time in the 30-km zone (typically 1.5-14 days) before they left the irradiated area and do not include the $^{131}$I doses to the thyroids.
In contrast to the evacuees, during the ten years from 1986 to 1995, the approximately 5,160,000 inhabitants of CRs overall, and the 193,000 residents of the ASCs within those areas in Russia, Ukraine, and Belarus, received similar cumulative radiation doses (see Table 2).

### Table 2

Mean cumulative effective doses per inhabitant of contaminated regions (CRs) including subgroups who continued to live in areas of strict control (ASCs) in Russia, Belarus and Ukraine. Estimated doses above natural background are from measurements of $^{137}$Cs in the indicated areas. Data from United Nations UNESCO 2000 report.

<table>
<thead>
<tr>
<th>Residence</th>
<th>$^{137}$Cs, KBq/m²</th>
<th>Population</th>
<th>External</th>
<th>Internal</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>CR</td>
<td>&gt; 37</td>
<td>5,159,487</td>
<td>4.7</td>
<td>3.6</td>
<td>8.3</td>
</tr>
<tr>
<td>ASC</td>
<td>&gt; 555</td>
<td>193,367</td>
<td>31.3</td>
<td>10.2</td>
<td>41.5</td>
</tr>
</tbody>
</table>

The mean external dose to the inhabitants accumulated during their ten years of residence in the ASCs was 31.3 mSv above natural background, remarkably similar to the average external dose received by Belarusian evacuees in the 1.5 to 14 days before their resettlement. The combined cumulative mean internal and external doses averaged 41.5 mSv for the ASC residents and 8.3 mSv for the total residents of the CRs. Due to radioactive decay and radionuclide migration, it is estimated that the doses received by the residents during the first ten years of life in the CRs, including the ASCs, is about 60 percent of the total life-time Chernobyl accident-related doses they will have received if they remain in those homes for the for the rest of their lives. Given that the mean cumulative natural background plus all of man-made and medical radiation in the United States is about 3.6 mSv per year, the ten-year cumulative mean Chernobyl radiation doses to residents of ASCs is less than 1.5 times the 10 year cumulative background dose to an average American.
Although the chronic nature of most of their total-body radiation exposures differentiates the inhabitants from the evacuees, there remain similarities in the exposures of their thyroid glands from $^{131}$I

**Radioiodine ($^{131}$I) and Childhood Thyroid Cancer**

Iodine is unique among elements in that it is an essential component of thyroid hormone that governs one’s metabolic rate and is essential for normal growth, development, reproduction, and cognitive functioning. Its blood levels are maintained by a thyroid-brain-pituitary feedback system. The common “stable” (non-radioactive) isotope of iodine is $^{127}$I. When iodine levels in the diet are normal, the thyroid gland concentrates and stores it against a thyroid-to-blood gradient of about 7:1. When the diet is iodine-deficient, the thyroid can concentrate iodine from the blood more than ten times as efficiently. If blood levels of thyroid hormone fall below normal or rise above normal, the brain tells the pituitary gland to secrete either more TSH (thyroid stimulating hormone) or less TSH, respectively, and the thyroid responds in an appropriate manner.

Atomic iodine vaporizes when warmed, and as such can enter the lungs and pass into the blood. As it cools, it readily enters water and the food chain on the surface of grasses, etc. Milk-secreting mammary gland tissue is the second most efficient concentrator of iodine in the body, and secretes the concentrated iodine attached to milk proteins. Dairy products were thus a rich food source of the radioactive iodine that entered children in the Chernobyl area.
Table 3

Estimated thyroid doses from intake of $^{131}$I for different ages of evacuees from the 30-km zone, Ukraine and Belarus. Data from United Nations UNSCEAR 2000 report. Some data are merged.

<table>
<thead>
<tr>
<th>Age at the time of evacuation</th>
<th>Belarus</th>
<th>Dose, Sv</th>
<th>Ukraine</th>
<th>Dose, Sv</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1 – 3</td>
<td>1,552</td>
<td>3.93</td>
<td>4,726</td>
<td>2.07</td>
</tr>
<tr>
<td>4 – 11</td>
<td>2,304</td>
<td>1.76</td>
<td>9,943</td>
<td>0.59</td>
</tr>
<tr>
<td>12-17</td>
<td>2,096</td>
<td>1.07</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>12-18</td>
<td>—</td>
<td>—</td>
<td>8,715</td>
<td>0.19</td>
</tr>
<tr>
<td>&gt;17</td>
<td>18,773</td>
<td>0.68</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>&gt;18</td>
<td>—</td>
<td>—</td>
<td>68,022</td>
<td>0.19</td>
</tr>
<tr>
<td>All Ages</td>
<td>24,725</td>
<td>1.02</td>
<td>91,406</td>
<td>0.33</td>
</tr>
</tbody>
</table>

Total Evacuees: 116,131; Overall Mean Thyroid Dose: 0.48 Sv

Unfortunately, iodine isotopes look alike to thyroid cells; they cannot distinguish between stable $^{127}$I and radioactive $^{131}$I, and concentrate any $^{131}$I present along with the stable $^{127}$I. If individuals of different ages are exposed to the same environmental concentration of $^{131}$I, the infant’s thyroid will absorb a higher radiation dose than an older child’s thyroid, and the latter will take in a higher dose than the thyroid of an adult. This age dependence is illustrated by the estimated radiation doses to the thyroids of evacuees (see Table 3).

About four years after the Chernobyl disaster, reports began to appear in the regional medical literature about increased thyroid cancer frequencies among children who had been exposed to $^{131}$I. Based on comparisons with the pre-accident frequencies of diagnoses of childhood thyroid cancer in the same area before the Chernobyl disaster, these claims were at first often dismissed as only anecdotal. Thyroid cancer generally is rare in children. It usually grows slowly, is often asymptomatic, and can be overlooked during routine medical examinations unless specifically sought. Because of these difficulties, it was thought that the reported frequencies of childhood thyroid cancer diagnoses before the catastrophe were likely to be underestimates of
the actual occurrence of childhood thyroid cancer in the pre-accident population.

Furthermore, although those exposed during childhood to therapeutic X-rays or to the A-bomb radiations in Japan did have increased thyroid cancer incidences, it was generally 10 to 15 or more years after the initial exposure that the overt cancers appeared. In the Chernobyl-exposed children, by contrast, the cancers tended to arise much sooner; the latencies of the first reported thyroid cancers in this group were less than half as long as that of the X-ray- or A-bomb-exposed children’s cancers. Adding to the difficulty, those patients who had received diagnostic or therapeutic doses of $^{131}$I as adults did not have an increased incidence of thyroid cancer. Because of these differences, it was therefore widely believed that the early reports of an increase in thyroid cancers among the Chernobyl-exposed children only reflected faulty pre-accident incidence figures and/or were due to random fluctuations in the occurrence of cancer.

Table 4
Numbers of thyroid cancers diagnosed and incidence per million children among those less than 15 years of age at times of diagnoses before (1981-1985) and after (1986+) the Chernobyl accident. Data from Goldman, 1997.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Belarus</td>
<td>3 (0.3)</td>
<td>47 (4.00)</td>
<td>286 (30.6)</td>
</tr>
<tr>
<td>Gomel Oblast</td>
<td>1 (0.5)</td>
<td>21 (10.5)</td>
<td>143 (96.4)</td>
</tr>
<tr>
<td>Ukraine</td>
<td>25 (0.5)</td>
<td>60 (1.1)</td>
<td>149 (3.4)</td>
</tr>
<tr>
<td>Northern 5 oblasts</td>
<td>1 (0.1)</td>
<td>21 (2.0)</td>
<td>97 (11.5)</td>
</tr>
<tr>
<td>Russia</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bryansk + Kaluga oblasts</td>
<td>0 (0)</td>
<td>3 (1.2)</td>
<td>20 (10.0)</td>
</tr>
</tbody>
</table>

However, thyroid cancers continued to be found in increasing numbers among the $^{131}$I-exposed inhabitant children as well as in the children evacuated from the contaminated regions. In Gomel, oblast thyroid cancer incidence increased from 0.5 cases per million children (a possible underestimate; see above) before the Chernobyl accident to 96.4 per million in the 1991-1994
period (see Table 4). Also, the distribution of childhood thyroid cancers among the youngsters evacuated from the 30-km exclusion zone paralleled the distribution of the measured $^{131}$I deposition within the zone. In addition, it became apparent that thyroid cancer incidence was greatest among those exposed during infancy, with the risk decreasing with the individual’s age at the time of exposure to the radiation. Some observers reported that the thyroid cancers in Chernobyl fallout-exposed children were more aggressive in growth rate and spread than the usual childhood thyroid cancers.

These observations aroused international interest, largely reversing the skepticism that had existed before, and stimulated collaborative efforts among thyroid experts and epidemiologists. What was initially widely considered to be anecdotal data of questionable import, is now seen to be an important biomedical effect of childhood exposure to $^{131}$I. Indeed, the 2000 UNSCEAR Report to the United Nations General Assembly estimates that approximately 1800 thyroid cancer cases had occurred among the evacuees and inhabitants who were exposed to Chernobyl accident radiations when children, and that more were likely to develop.

A major new collaborative project involving experts from Belarus, Ukraine, and the U.S. is now in progress. A cohort of 25,161 Belarusians and Ukrainians who were less than 18 years of age at the time of exposure to Chernobyl fallout $^{131}$I in 1986 were chosen for study. New individual thyroid dose estimates are being developed for each individual on the basis of 1986 thyroid scans for $^{131}$I content, the intake of dairy products from family interviews, and contamination of their immediate areas by fallout. The subjects will be examined every two years for a minimum of three cycles, and suspected cancers will be confirmed by biopsy. Already, more than 100 new cases of thyroid cancer have been diagnosed during the first round of examinations. The researchers will also investigate other radiation effects on the thyroid gland, including the development of non-cancerous thyroid nodules, and of hypothyroidism (inadequate thyroid hormone) and hyperthyroidism (excessive thyroid hormone). This prospective study is well designed to reveal the details of the radiation dose-cancer response and the effects of sex, age at exposure and other factors on thyroid cancer induction.

One remaining question is why the latency periods for Chernobyl accident-related childhood thyroid cancers were so short compared with those for thyroid cancers initiated by external irradiation of children? The answer lies in the feedback regulation system of the thyroid and the availability and control of iodine uptake. The Chernobyl region is known to be an area only borderline in the amount of iodine available for optimal thyroid development. A scarcity of dietary iodine impairs the thyroid’s capacity to maintain normal thyroid hormone levels, thereby bringing about a chronic increase in TSH release. TSH stimulates the hormone-secreting thy-
roid cells to concentrate more iodine, including $^{131}$I if this isotope is present. The greater the concentration of $^{131}$I, the greater is the radiation dose to the thyroid, particularly in children. Should the iodine deficiency persist because of an inadequate supply of iodine in one’s diet, as was often the case in the area around Chernobyl, chronically elevated TSH stimulates the thyroid stem cells to proliferate, forming more hormone-secreting cells. Any thyroid stem cells that have been “initiated” (started on the multi-step process of cancer formation) by exposure to radiation are therefore stimulated to proliferate, and this elevated proliferation of pre-cancerous thyroid stem cells hastens cancer development and shortens cancer latency.

Has the risk of thyroid cancer also increased among evacuees and inhabitants who were exposed when adults to Chernobyl accident radiations? Nineteen years after the Chernobyl disaster, there has not been a great increase in the chances of thyroid cancer among those exposed as adults. It is likely that any increased probability of this disease that might occur is significantly less than the chance of cancer arising in children. First, the $^{131}$I doses to adults’ thyroids were less than those to the children’s. Second, virtually all of the increase in thyroid cancer incidence among the Japanese A-bomb survivors is attributable to cancers in those exposed when less than twenty years of age, and most of that increase was among those who were less than 10 years old when the bombs were dropped.

It is common practice to express the increase in cancer risk due to a given radiation dose as a fraction of the risk in an unirradiated but otherwise comparable population. Thus, a group of hibakusha boys less than 10 years old when they were exposed to 1 Sievert A-bomb radiations had their risks of thyroid cancer increased by 9.39 times the risk they had before radiation exposure. In short-hand, this is termed the excess relative risk (ERR) per unit of radiation dose (here, 1 Sv), or in shorthand, their ERR Sv$^{-1}$ = 9.39 (Table 5).

### Table 5

<table>
<thead>
<tr>
<th>Excess Relative Risk (ERR / Sv$^{-1}$)</th>
<th>Age at exposure, years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0-9</td>
</tr>
<tr>
<td>Males</td>
<td>9.39</td>
</tr>
<tr>
<td>Females</td>
<td>9.47</td>
</tr>
<tr>
<td>Both sexes</td>
<td>9.46</td>
</tr>
</tbody>
</table>
The Liquidators

Tasks and Estimated Radiation Doses

From 1986 through 1989, about 600,000 persons, including approximately 240,000 military personnel, served three-month tours of duty as liquidators. (Note that there is some confusion in the literature between the terms emergency worker and liquidator, but in this chapter the terms are used as equivalent). Most liquidators were 20- to 45-year-old males. They worked on construction and decontamination of the 30-km zone and in other heavily contaminated regions outside the zone. The liquidators’ most important jobs in the period from May to November 1986 were to decontaminate the site of Reactor Number 4, help stabilize the ruins, and enclose them in a “sarcophagus” that would prevent further contamination. The liquidators who worked in the 30-km zone during 1986 received higher average doses than those who worked there later (see Table 6).

Table 6


<table>
<thead>
<tr>
<th>Country</th>
<th>No. of Liquidators</th>
<th>Percent with known dose</th>
<th>Mean</th>
<th>95th percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td>1986</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Belarus</td>
<td>20,000</td>
<td>28</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Russia</td>
<td>69,000</td>
<td>51</td>
<td>169</td>
<td>250</td>
</tr>
<tr>
<td>Ukraine</td>
<td>98,000</td>
<td>41</td>
<td>185</td>
<td>326</td>
</tr>
<tr>
<td>All</td>
<td>187,000</td>
<td>45</td>
<td>170</td>
<td>NA</td>
</tr>
<tr>
<td>1986-1989</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Belarus</td>
<td>63,000</td>
<td>14</td>
<td>43</td>
<td>119</td>
</tr>
<tr>
<td>Russia</td>
<td>148,000</td>
<td>63</td>
<td>107</td>
<td>240</td>
</tr>
<tr>
<td>Ukraine</td>
<td>170,000</td>
<td>56</td>
<td>126</td>
<td>293</td>
</tr>
<tr>
<td>All</td>
<td>381,000</td>
<td>52</td>
<td>113</td>
<td>NA</td>
</tr>
</tbody>
</table>

The smallest percentages of liquidators with a “known dose” were from Belarus, averaging but 14 percent of that group over the four-year period, and the estimated doses in Belarus were the
lowest reported each year (as is shown in Table 6, columns 3 and 4). Ninety-five percent of the individual doses lay at or below the “95 percentile” figures (listed in the fifth column, Table 6, when available). The highest mean dose for 1986 was 185 mSv with a 95 percentile of 326 mSv. The mean doses for 1986 and for all four years were 170 and 113 mSv, respectively. These statistics suggest that not very many liquidators were likely to have received total-body radiation doses equal to or greater than 500 mSv, the threshold acute dose for ARS.

Individual personnel dosimeters were not available during much of the time after the Chernobyl accident in which the liquidators were working. Dose estimates were therefore calculated either from measurements made by a dosimeter carried by the leader of a working party, or were estimated from the time individual workers spent in areas in which dose rates had been measured.

The data summarized in Table 6 is drawn from 381,000 of a purported 600,000 liquidators, indicating that the records of perhaps as many as 220,000 liquidators are not included. Furthermore, there are discrepancies in the numbers given in the various reports of the liquidators’ health status. The late 1980s is the period during which the USSR was in the process of dissolution. It is to the great credit of those who preserved them that the records cited here were saved during that chaotic period and are available now.

Radiation doses to the thyroids of 600 early liquidators were estimated from measurements of thyroid $^{131}$I contents. Their average thyroid dose was 21 mSv. Eighteen of them (3 percent) had doses of 750-3,000 mSv and about 200 (approximately 33 percent) had doses of 150-750 mSv. Remaining doses were less than 150 mSv.

**Cancers in the Survivors of Chernobyl and the Atomic Bombings**

The health of the survivors of the A-bombing of Hiroshima and Nagasaki, Japan, was first monitored by the Atomic Bomb Casualty Commission (ABCC) founded by the U.S. in 1947. In 1975, its successor, the Radiation Effects Research Foundation (RERF), was established by treaty as a binational Japanese-American institute; it inherited the ABCC facilities, staff, records and dedication and the work has continued without interruption. The A-bomb survivors are termed *hibakusha* in Japanese, a word referring to citizens of either city at the time of the bombing regardless of whether they were irradiated. Because of the size and character of the study cohort and the nature of the radiation exposures, the results of the major ongoing studies of ABCC/RERF are the yardstick against which most other investigations of radiation effects in humans are assessed.
Approximately 120,000 *hibakusha* drawn from both cities were chosen as the cohort for the prime project, the Life-Span Study (LSS). Like the Chernobyl evacuees and inhabitants, the LSS cohort was comprised of people of all ages and both sexes. In contrast, the Chernobyl emergency workers and liquidators were largely 20- to 50-year-old males.

About 50 percent of the LSS cohort had received A-bomb radiation doses of 10 mSv to more than 4,000 mSv. The other half of the cohort had been exposed to little (less than 10 mSv) or no radiation because they had been either shielded or were far away from the bomb blast. This latter very-low-to-no-dose group is uniquely similar to the irradiated group except in radiation exposure. The *hibakusha* irradiation was instantaneous over their whole bodies. It was comprised of gamma rays and a small component of accelerated neutrons, both released from atomic fissions during the explosions. The bombs were detonated more than 500 m above ground and the radioactive products were immediately dispersed and diluted in the upper atmosphere. Hence, there were no significant additions to the *hibakusha* total doses from locally deposited fallout radionuclides.

The wide range of people and radiation doses in the LSS was a great advantage in that it made it possible to design *prospective projects*, i.e., projects that involve surveillance of a cohort and collection of data according to a predetermined pattern chosen to minimize sources of bias. The LSS project is continuing; sixty years after the bombings, with 40 to 45 percent of the *hibakusha* cohort still alive. Given a sufficient dose range, the prospective design allows data analyses of the relationships of radiation dose to biological effect that can determine whether radiation acts as a causative agent. The project is not heavily dependent on a pristine control group that differs from the irradiated population only in a total absence of radiation exposure. Rather, the low dose survivors serve to anchor the low end of the dose-response curve. The LSS can serve as an example that can be useful in future studies of the Chernobyl fallout victim groups without dependence on questionable unirradiated dose control populations. Such projects are currently being designed or are in early stages with Chernobyl-irradiated cohorts.

The Chernobyl catastrophe’s emergency workers had received the highest dose rates of any of the groups that had been exposed to the accident-caused radiation. Some early liquidators who worked on construction of the sarcophagus might also have received similarly high dose rates. Excluding those cases in which the $^{131}$I doses to their thyroids came from internal sources, the radiation exposures of most liquidators, probably as well as all of the evacuees and all of the inhabitants, were at dose rates that were very likely less effective than the same doses delivered instantaneously by the A-bombs. The effectiveness of a radiation dose delivered at high dose rate in a single exposure is greater by a factor of two to ten or more than the effectiveness of the same total dose either delivered at a low dose rate and/or divided into several
smaller dose fractions. Many cells have repair systems and many tissues have cell replacement systems that can function concurrently with low dose-rate radiation exposures and during pauses between radiation fractions. For example, one would expect that a given radiation dose accumulated over ten years from Chernobyl accident fallout by an inhabitant of a contaminated region would be very significantly less effective than the same total dose delivered instantaneously to an hibakusha by an A-bomb explosion.

Lymphocytic leukemia, i.e., hematologic cancer of lymphocytes, increased in irradiated hibakusha children before any other cancers were detected, with a latency of 3-4 years and a peak incidence at about 5 years. Several types of leukemia have continued to occur in irradiated hibakusha of all ages at significantly higher than normal frequencies throughout the LSS follow-up (Table 7).

Table 7


<table>
<thead>
<tr>
<th>Leukemia type</th>
<th>No. Leukemias seen in:</th>
<th>Excess Cases at 1 Sr</th>
<th>ERR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control (&lt;0.01 Sr)</td>
<td>Irradiated (0.01-4.0 Sr)</td>
<td></td>
</tr>
<tr>
<td>Acute Lymphocytic</td>
<td>9</td>
<td>13</td>
<td>16.9</td>
</tr>
<tr>
<td>Acute Myelogenous</td>
<td>43</td>
<td>60</td>
<td>29.8</td>
</tr>
<tr>
<td>Chronic Myelocytic</td>
<td>17</td>
<td>40</td>
<td>25.8</td>
</tr>
<tr>
<td>Other</td>
<td>7</td>
<td>8</td>
<td>5.5</td>
</tr>
<tr>
<td>All Leukemias</td>
<td>90</td>
<td>131</td>
<td>74.9</td>
</tr>
</tbody>
</table>

Thereafter, increases in a variety of cancers were the most common cause of radiation dose-related morbidity and mortality among hibakusha. Thyroid cancer was the first non-hematologic solid cancer to increase among irradiated LSS hibakusha after a latency of 10-15 years. A dozen or more other solid cancer types also increased significantly during a 29 year follow-up. Thyroid cancer increased about 120 percent per Sv, and breast cancer, the most common radiation-related cancer of women, increased approximately 160 percent of the control.
rates per Sv (Table 8, ERR Sv\(^{-1}\)). About 32 percent and 26 percent of the total breast cancers and thyroid cancers, respectively, in the whole hibakusha cohort were attributable to the atomic bomb radiation exposures (Table 8, AR percent). Overall cancer risks and especially breast and thyroid cancer risks were significantly higher in those exposed to radiation when children than when irradiated as adults.

### Table 8


<table>
<thead>
<tr>
<th>Cancer types/sites</th>
<th>Percent total cancers</th>
<th>ERR Sv(^{-1})</th>
<th>AR percent *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total solid cancers</td>
<td>100.0</td>
<td>0.63</td>
<td>11.6</td>
</tr>
<tr>
<td>Female breast</td>
<td>6.1</td>
<td>1.6</td>
<td>31.9</td>
</tr>
<tr>
<td>Thyroid</td>
<td>2.6</td>
<td>1.2</td>
<td>25.9</td>
</tr>
</tbody>
</table>

*AR percent = attributable risk, percent = percent of cancers that are attributable to radiation exposure.

The Russian National Medical Dosimetric Registry (RNMDR) contains the records of 167,862 liquidators who served in the period 1986 through 1989 and resided in the Russian Federation after the dissolution of the USSR. Making use of the annual medical examinations these people had received, an inspection of the records of 119,416 of these liquidators found 47 confirmed thyroid cancers by January 1, 1995. There was a rise in thyroid cancer diagnoses 4 to 5 years after their services in the contaminated areas. When compared to the national Russian male cancer statistics, an ERR Sv\(^{-1}\) of 5.3 was calculated.

There are several reasons for caution in interpreting these data. Only estimated radiation doses from external sources are considered, and these averaged about 140 mSv for the liquidators with thyroid cancer. Because of the lack of personnel dosimeters, the radiation dose estimates are open to substantial uncertainty. The Russian national male control data with which liquidator thyroid cancer incidences were compared are referred or volunteered data. For example, the liquidators’ cancer incidences are based on examinations performed by specialists, whereas the “control” data with which they are compared come from examinations often performed by medical generalists with unknown training and experience in cancer detection and diagnosis on patients with unknown backgrounds. Furthermore, we do not know to what degree the medical practitioners had complied with the request to report cancer diagnoses to the Rus-
sian cancer registry. Since this latter kind of data usually underestimates the actual cancer incidence significantly, the investigators used a multiplication factor as a “correction.” In addition, internal $^{131}$I doses to the thyroids might have been important in the cancer initiation, particularly among liquidator groups who were present at, or soon after, the major releases of $^{131}$I from the reactor ruins. Yet another question has to do with the apparent five-year minimum latency period before the cancer appeared. This latency is about half as long or even less than that observed in other studies of radiation-induced thyroid cancers among individuals exposed to external radiation as adults. If the reported short latency is valid, it very likely is due to the dietary iodine insufficiency in the Chernobyl area as is the case with Chernobyl childhood cancer.

In a later study, medical records of 114,504 Russian male liquidators collected during a ten-year period 1986-1996 were selected from the RNMDR for analysis. At the time they arrived at the Chernobyl site these subjects were on the average 34 years of age, with a range of 15-60 years. They worked in the 30-km zone for approximately 2.7 months and received total-body doses averaging 108 mSv. A total of 983 solid cancers were diagnosed among these liquidators during the ten year period; 301 of these cancers originated in the digestive system. When compared to Russian national male cancer data, the ERR Sv$^{-1}$ for total solid cancers in the liquidators was 1.13 and for intestinal cancers was 2.41; both ERRs are statistically significant and unusually large. No other individual cancer incidences were statistically different from the national cancer data. These observations are subject to the same cautions as the thyroid cancer data noted above because of the dosimetry problems and the use of the Russian national male cancer incidence as the control data. The investigators were aware of these problems, and suggested that further study was justified and desirable.

Comparing the Effects of the Chernobyl Accident and the Atomic Bombs

**Non-Cancer Diseases and Conditions**

A study of 65,905 male liquidators’ RNMDR medical records from the period 1991 to 1998, two to twelve years after irradiation, revealed 4,995 deaths, a 7.6 percent mortality (Table 9). Cancer accounted for about ten percent of the deaths and was highly correlated with radiation dose. Cardiovascular disease accounted for approximately 35 percent of the deaths overall and was increased somewhat with radiation dose.
Table 9


<table>
<thead>
<tr>
<th></th>
<th>All cancers</th>
<th>Injuries and Poisons</th>
<th>Cardiovascular disease</th>
<th>All but cancer</th>
<th>All causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. Deaths</td>
<td>515</td>
<td>1,858</td>
<td>1,728</td>
<td>4,480</td>
<td>4,495</td>
</tr>
<tr>
<td>% all Deaths</td>
<td>10%</td>
<td>37%</td>
<td>35%</td>
<td>90%</td>
<td>100%</td>
</tr>
<tr>
<td>ERR Sv⁻¹</td>
<td>2.11</td>
<td>-0.36</td>
<td>0.54</td>
<td>0.13</td>
<td>0.27</td>
</tr>
</tbody>
</table>

Interpretation of these data is clouded by the fact that there is a “healthy worker effect,” i.e., the mortality rates of the liquidators were less than the control mortality rates from the Russian male statistics bank. Such a phenomenon can occur if the group under study had previously been either self-selected, or selected by others, as being relatively healthy, and this was the case, with the liquidator candidates; they had been “subject to additional medical checks” before they were sent to the accident site. Additional statistical procedures were therefore used to “correct” for this problem in the analysis. Yet another uncertainty is that a radiation effect on cancer deaths in many of the liquidators so soon after radiation exposure is inconsistent with observations of other irradiated populations.

Returning to the comparison with the A-bomb consequences, a 47 year LSS follow-up study found that 71 percent of the mortality among an initial cohort of 86,572 hibakusha was attributable to non-cancer diseases (Table 10). Sixty percent of the hibakusha group were exposed to from 5 to more than 4000 mSv of A-bomb radiations, and the follow-up period began five years after exposure. Although the overall ERR Sv⁻¹ for mortality from all solid cancers was 0.47, the ERR Sv⁻¹ values were higher for those irradiated during childhood. Overall, 554, or 6 percent, of the solid cancer deaths were attributable to radiation exposure.
Table 10


<table>
<thead>
<tr>
<th>No. of <em>hibakusha</em></th>
<th>All deaths</th>
<th>Solid cancers</th>
<th>Leukemias</th>
<th>Benign tumors</th>
<th>Blood disease</th>
<th>Non-cancer disease</th>
<th>External and unknown</th>
</tr>
</thead>
<tbody>
<tr>
<td>86,572</td>
<td>44,771</td>
<td>9,335</td>
<td>582</td>
<td>447</td>
<td>222</td>
<td>31,881</td>
<td>2,304</td>
</tr>
<tr>
<td>% of deaths</td>
<td>100%</td>
<td>21%</td>
<td>1%</td>
<td>1%</td>
<td>0.5%</td>
<td>71%</td>
<td>5%</td>
</tr>
</tbody>
</table>

*M* Hemopoietic diseases with unclear relationships to leukemias.

Mortality among the *hibakusha* cohort during the most recent available 30-year period was analyzed separately. Deaths from non-cancer conditions increased linearly with an ERR Sv⁻¹ = 0.14. Of the 14,459 *hibakusha* deaths from non-cancer causes, 273, or about 2 percent, were attributable to the irradiation; heart disease and stroke accounted for 165 deaths or 60 percent of the radiation-related non-cancer mortality. Respiratory disease and digestive disease also increased significantly.

It is important to note that mortality from infectious diseases did not increase significantly after irradiation in either *hibakusha* analysis. This is of interest because claims have been made that there is a reduced resistance to infection among some survivors of radiation exposures (See section on “radiation AIDS”, etc. below).

Benign thyroid diseases, including thyroid nodules, fibrosis, inflammatory disease, hypothyroidism, and perhaps hyperthyroidism, may become important with time among some groups of Chernobyl victims. Hyperparathyroidism and associated hypercalcemia (high blood calcium) and osteoporosis (decalcification of bones) with benign parathyroid gland tumors or hyperplasia may also develop in some of this population. Hyperparathyroidism correlated with radiation dose in a small *hibakusha* study. The four small parathyroid glands lie immediately adjacent to the thyroid and may also have received scattered radiation from thyroidal ¹³¹I as well as from external radiation.
The Next Generation

The fear of mutant monster offspring was common among the irradiated hibakusha, as it has been among the Chernobyl-irradiated groups. The first study of ABCC was to determine if major deleterious mutations had passed via irradiated hibakusha germ cells to their progeny. At the time that Japanese women who conceived after the bombings reached the fifth month of pregnancy and applied for additional rations, ABCC enlisted them in a program in which their health and that of their babies was monitored during the balance of their pregnancies and for a period afterwards. Better than 90 percent of the pregnant women joined the program. The ABCC observations included the mother’s health during pregnancy and birth, miscarriages, stillbirths and newborn deaths, the baby’s birth size and any gross abnormalities, reflex test responses, and postnatal development during the first nine months. After six years of the project, 71,013 pregnancies and births had been monitored and the study was terminated. Offspring conceived after the bombings whose mothers and/or fathers had been irradiated did not differ in any of the observed endpoints from babies whose parents had not been exposed to A-bomb radiation. There were no mutant monsters!

Searches for new mutant genes and abnormal chromosomal exchanges in the progeny of irradiated and hibakusha not exposed to radiation also yielded largely negative results. The radiation doses received by the parental germ cells and hence the mutation frequencies, were apparently too low to be detected by the methods available at the time. Cells of the parents and children are now held frozen in suspended animation until the molecular technology is sufficiently refined to directly compare the offspring and parental genomes.

The attempts to find new mutations among the progeny conceived after exposure by Chernobyl-irradiated parents have not been highly fruitful. It is doubtful that radiation-induced mutations will be of great importance in the lives of these offspring.

A small group of very damaged children are progeny of hibakusha women who were A-bomb-exposed while pregnant. Some of the children suffered mental retardation so severe that they were unable to care for themselves. This affliction was associated with disruption of development of the embryonic brain by radiation exposure 8 to 15 weeks after fertilization, and to a lesser extent, in the following two months or so. The frequency of such damage was directly related to the radiation dose; e.g., approximately 25 percent of those exposed to about 0.6 Sv and about 70 percent of those receiving about 1.3 Sv, when they were in their mothers’ wombs during weeks 8-15 of pregnancy, were severely retarded. Several of these children also had ab-
normally small heads and reduced body growth. In addition, radiation exposure during these two critical periods after fertilization also reduced school performance and IQ in proportion to the dose received among children who were less damaged and able to attend school. These damages are not due to mutations in parental germ cells; rather, they are radiation effects on embryonic differentiation and growth. Whether the Chernobyl fallout led to similar embryonic damage among the victims’ progeny evidently depends on whether the women were two to six months pregnant and had received sufficient radiation exposure to their developing embryos.

A related concern is the possible effects of radiation exposure on fertility. The acute threshold doses for temporary infertility are about 0.15 Sv to the testes and 0.65-1.5 Sv to the ovaries. Threshold doses for permanent sterility are 3-5 Sv in males, 6.25 Sv in young females, and less in older women.

The *hibakusha* experience shows that the fear of parenting offspring with radiation-induced deleterious gene mutations was exaggerated. It is also likely to be exaggerated among the Chernobyl-irradiated groups. And although a radiation-caused, severely-retarded offspring may be a profound personal and family tragedy, this nevertheless is a rare event of little or no consequence to the familial or species gene pools. The amount of Chernobyl-produced radiation to the gonads sufficient to lead to a permanent sterilization would necessarily mean there was a total body irradiation at the same or higher doses, and at this level of exposure infertility would not necessarily be the irradiated individual’s prime concern.

*Radiation AIDS, Genbaku Bura-Bura, Chernobyl-Hearts, Vegeto-Vascular Dystonia, and the Like*

Some members of Chernobyl-irradiated groups, particularly the evacuees and inhabitants, like some of the *hibakusha*, have attributed a variety of conditions and symptoms to their radiation exposures. A good number of *hibakusha* have termed constellations of the subjective symptoms experienced by the victims *Genbaku Bura-Bura* (atomic bomb lingering disease), and the evacuees and inhabitants of the bombed areas have referred to some of these aftereffects as “Radiation AIDS.” Whatever the labels given these effects, common among the symptoms and complaints are fatigue, muscle weakness and lassitude, miscellaneous back, shoulder, neck and head pains, palpitations and vertigo or dizziness, as well as an increased susceptibility to infectious diseases, to name a few. (It is important here to note that mortality from infectious diseases was not increased among irradiated *hibakusha.*) Medical examinations have not shown a connection between the nebulous group of symptoms and radiation exposure. Indeed, an expert
A condition termed “Vegeto-Vascular Dystonia” is described as involving a loss of muscle tone, especially in the circulatory system, and has been diagnosed among some liquidators. No correlation with radiation exposure has been established. This condition is without a recognized equivalent in western medicine.

The term “Chernobyl heart,” referring to a specific congenital cardiac malformation, has been widely publicized in a film documentary, television program, and press reports, all claiming that this defect occurred in unusually high frequency in babies born to Chernobyl fallout-exposed people in Ukraine. After a flurry of public concern in the Chernobyl area and the West, reexamination of the records revealed that this condition actually was a familiar congenital malformation that occurred in equal frequencies among the progeny of unirradiated as well as irradiated parents.

Given that the populations afflicted by the radiation from either the Chernobyl fallout or the A-bomb suffered enormous upheavals and losses from disasters over which they had no control, and that the lives they have led since this catastrophe often have little resemblance to the living conditions they had experienced before, it is not surprising that many have succumbed to anxiety, melancholy, fatalism, inertia and despair---and that the incidences of alcoholism, suicide and somatization have increased in both communities.

Summary and (My Personal) Interpretations

The people exposed to radionuclides from the burning core of Chernobyl Reactor Number 4 do not all have the same biomedical experiences and problems. A good number differ from the others because of the extreme radiation dose they received and/or the extent of their burns or because of other highly aversive experiences they had, and there are still other smaller groups of irradiated individuals who do not easily fit in any of the major categories we’ve discussed.
These differences illustrate the variety of current and possible future biomedical problems associated with the Chernobyl catastrophe, some directly attributable to the radionuclides released by the accident and some that are not. They also highlight the roadblocks to be overcome in reaching appropriate conclusions concerning their etiology, treatment and prevention in the future.

The approximately 820 emergency workers are by far the most damaged group. Most were male reactor technicians, firefighters, or emergency medical personnel who realized, at least to some extent, that they were placing themselves in harm’s way. Many suffered cutaneous radiation burns to much of their bodies, as well as high doses of deeply penetrating radiation. For example, 85 percent had total-body doses equal to or greater than 0.5 Sv and some had approximately 1.2 to as high as 23 Sv of $^{131}$I radiation to their thyroid glands. They have increased risk of thyroid conditions, including fibrosis, inflammatory disease, hypothyroidism, benign thyroid nodules, and perhaps thyroid cancer and hyperparathyroidism. Two emergency workers died at the reactor site, and 28 died in hospital with acute radiation syndrome and cutaneous burns for an overall acute mortality of about four percent. Those with radiation burns will continue to have problems with fibrosis, ulceration, and high risks of skin cancer. As a group they will also suffer risks of several radiation-related cancers, benign diseases, and overall life shortening. These are special people who are deserving of medical aid for the rest of their lives.

There are about 116,000 evacuees of both sexes and all ages with external radiation doses averaging 17 mSv in Ukraine and 31 mSv in Belarus, although there were some persons who received as much as 400 mSv or even more. Given the mean adult thyroid dose estimates of 190 mSv and 680 mSv internal $^{131}$I in Ukraine and Belarus, respectively, coupled with the local dietary iodine deficiency, some adults may suffer the same spectrum of benign thyroid diseases as the emergency workers though their incidence of thyroid cancers may not be greatly increased. The parathyroid glands are close to the thyroid (“para” means “next to”) and may also have received some radiation from thyroidal $^{131}$I. Benign parathyroid tumors that produce hyperparathyroidism and osteoporosis increased with radiation dose in some hibakusha. Exclusive of thyroid and perhaps parathyroid problems, only those who received doses at the upper extremes are likely to have major increases in radiation-related risks of cancer or non-cancer diseases.

As well as the thyroid $^{131}$I doses received soon after the Chernobyl accident, the combined external and internal total body radiation doses to the 5,200,000 adult inhabitants of the contaminated regions in Russia, Ukraine and Belarus, averaged about 8.3 mSv above natural background accumulated during the decade following the Chernobyl accident. Inhabitants of the ASCs (areas of strict control) are estimated to have accumulated five times the overall average.
dose in the contaminated regions or approximately 41.5 mSv during the decade. To put this in perspective, the average radiation dose accumulated over ten years by an American from natural radiation background sources is about 30 mSv; an additional 6 mSv or so is accumulated per decade from man-made sources and medical applications. Given the low total doses and their extremely low rate of dose delivery, it is unlikely that the inhabitants who were not exposed during childhood will have detectably increased risks of radiation-related benign or malignant diseases. A possible exception is the $^{131}$I-related spectrum of benign thyroid conditions, rare thyroid cancer, and perhaps hyperparathyroid problems.

Despite the skeptics, the bad news concerning the evacuee and inhabitant children who were exposed to high $^{131}$I doses to their thyroids is that they have been or continue to be at high risk of thyroid cancer. The good news is that few, or perhaps none, of them have developed childhood lymphocytic leukemia, the first malignant disease to be associated with the atomic bomb irradiation. Among irradiated hibakusha children, the first increases in lymphocytic leukemia became apparent within three to four years after the bombings, and peaked five years after exposure. Leukemias of a variety of types developed progressively later in hibakusha that were progressively older at the time of exposure. Nineteen years after the Chernobyl reactor disaster there is no evidence of an increase in lymphocytic leukemia among the irradiated evacuee children. And other leukemia types have apparently not occurred in greater frequency than would be expected in the absence of irradiation among evacuees who were adults at the time of exposure.

The several types of leukemia are diseases that are difficult to ignore; they make people very sick, are not difficult to diagnose, and are frequently fatal. The absence of evidence of a wave of leukemia among the evacuee children indicates that many of them received local radiation doses to their thyroids sufficient to cause thyroid cancers, but they did not receive sufficient total body radiation doses to their hemopoietic cells to initiate leukemia. Children are more sensitive to the overall cancer-initiating effects of radiation than are adults. It is possible that some females exposed as children will have an increased susceptibility to breast cancer. They should be monitored for this possibility. The increase in the risks of most if not all other cancers among the evacuees who were adults as well as among those who were children are likely less than expected from hibakusha with comparable total body doses. These considerations apply with greater force to the adult inhabitants because of their very protracted radiation doses.

As for the liquidators, it is difficult to predict. There has not been a large increase in leukemia among them. The mean total body estimated radiation dose to liquidators who worked dur-
ing the first two years after the Chernobyl accident are within the hibakusha dose range for significantly increased leukemia and solid cancer risks. Also, some early liquidators may have received the same radiation exposures as the emergency workers—indeed, much the same terminology has been used in discussing these two groups in some of the literature. However, the fractionated delivery of the radiation doses over time to most liquidators is likely to have reduced the total dose effectiveness.

The uncertainties mentioned before about individual dose estimates and the data regarding the disease frequencies in the unexposed “control” groups make it difficult to have confidence in both much of the early literature on the biomedical effects of exposure to the Chernobyl accident-produced radiation, and also in the speculation about the future. A prospective study of the liquidators comparable to the large prospective thyroid cancer project now in progress can make a major contribution. In any event, it is likely that the total-body radiation doses most liquidators received produced reduced long term potential damage because of the reduction in radiation effectiveness from the low rate of delivery and the fractionation of the doses.

There are many estimates as to how many individuals have suffered or will suffer morbidity and mortality as a consequence of their exposure to the radionuclides released by the Chernobyl catastrophe. Quite a few of these estimates assume the risk levels per unit dose figure published by the Committee on the Biological Effects of Ionizing Radiations V (BEIR V) of the U. S. National Research Council or from another comparable group. Sometimes these risk levels are applied to large populations using dosage estimates assumed from measurements of fallout radioactivity in regions remote from Chernobyl and often without consideration of local conditions of shielding, soil porosity etc., and of the likely effects of dose rate and dose fractionation on biological effectiveness. Such figures are often inflated or deflated beyond reality, are misleading, and are too frequently used for political purposes.

The current discussion has focused on the four populations that received the highest radiation doses from nuclides released by the burning core of Chernobyl Reactor Number 4. Each of these groups is subject to a different spectrum of problems because of the unique natures of their radiation exposures, and hence, all may not experience the same biomedical consequences at present and/or in the future. Perhaps this paper may in a small way encourage continued research to reach a more complete knowledge of reality.
ADDENDUM
Kelly H. Clifton

Coincident with the completion of this chapter, an important report entitled Chernobyl’s Legacy: Health, Environmental and Socio-Economic Impacts was released in September 2005 by the United Nations. This 600-page UN-sponsored analysis, dealing to a considerable extent with the topics covered in my chapter, was prepared by a Forum comprised of over one hundred scientists, health experts, and economists. Attesting to the authors’ qualifications, the Forum’s chair was Dr. Burton Bennett, a public health expert and immediate past chairman of the Radiation Effects Research Foundation (RERF), the binational institute that is dedicated to the long-term study of the A-bomb survivors of Hiroshima and Nagasaki. The Forum included representatives of the governments of Belarus, Ukraine, and Russia and of eight agencies of the United Nations including the World Health Organization, the UN Scientific Committee on the Effects of Atomic Radiation, the Food and Agriculture Organization, and the International Atomic Energy Agency.

Although my chapter and the Forum report deal with the same groups known to have been exposed to Chernobyl accident-related radiations, there are some differences in the numbers of people included in each of the groups of interest. The Forum members surely had access to a greater volume of recent, and perhaps more accurate, data than was available during the writing of the chapter, and there are some differences in the classifications of individuals into particular risk groups. Despite these, the conclusions reached are not substantively different.

The Forum summary states “approximately 1,000 on-site reactor staff and emergency workers” were present during the reactor fire, whereas my chapter refers to a group of about 820 “emergency workers,” comprised of reactor staff, firemen, and non-technical workers who were present. In these groups, the Forum reports that fewer than 50 deaths (less than 5 percent mortality) resulted directly from radiation exposure, predominantly during the first few months after the accident, but with some as late as 2004. The chapter notes 30 such deaths among the 820 “emergency workers” within a few months after the accident (a 3.7-percent mortality). Based on their estimations of radiation doses and other injuries, both reports conclude that this group of emergency workers in particular will continue to be at high risk of radiation-related malignant and benign health conditions and premature mortality for the remainder of their lives.

Another group, the cleanup, decontamination and construction workers, termed “liquidators” in my chapter, performed three-month tours of duty in radionuclide-contaminated areas during the period 1986 through 1989. Some of the first liquidators took part in cleanup
and construction of the containment “sarcophagus” around the ruined reactor core. They received higher radiation doses than other liquidators; some of their total-body doses were likely in the range of the emergency workers’ doses. Due to radionuclide decay and natural migration, radiation intensities in the contaminated areas decreased with time after the reactor accident. The numbers of liquidators for whom mean estimated cumulative radiation doses were given in the chapter were 187,000 liquidators exposed to 170 mSv radiation in 1986, 107,000 liquidators exposed to 130 mSv in 1987, 45,500 liquidators to 30 mSv in 1988 and 42,500 liquidators to 15 mSv in 1989. The difficulties in determining the numbers of liquidators, estimating their radiation doses, and determining their morbidity and mortality were discussed in the chapter. However, because the 1986 and 1987 liquidators together are the largest group that received significant total-body radiation doses, they may be an appropriate group for future studies.

The Forum summary estimates that “more than 200,000 emergency and recovery operation workers” were active during 1986 and 1987, roughly corresponding to the 294,000 combined 1986-87 liquidators described in the chapter. The Forum concludes that about 2,200 radiation-related deaths might occur among this group during their lifetimes. They also maintain that the radiation doses received by the 1988-89 liquidators were insufficient to cause detectable numbers of radiation-related health problems.

As both reports note, about 116,000 residents, including many whole families, were removed from the exclusion zone soon after the accident and resettled away from further radiation exposure. My chapter estimates that the total-body radiation doses to the Ukrainian and Belarusian evacuees averaged about 17 and 31 mSv, respectively. They were irradiated during the 1.5 to 14 days that elapsed from the start of radionuclide emissions from the burning reactor core until their evacuations from the exclusion zone. The Forum believes that some of these individuals were likely to have received radiation doses great enough to render them susceptible to long-term radiation-related morbidity or mortality.

Both reports also note that approximately 5,000,000 individuals continue to live in radionuclide-contaminated regions, of which, according to the Forum, about 100,000 still reside in high background “areas of strict control” (ASCs). My chapter indicates that approximately 193,000 inhabitants lived in ASCs a decade after the accident; the difference in numbers is at least partially related to voluntary individual and family relocations outside the ASCs. The overall calculated total-body radiation dose accumulated by individuals during the first decade of residence in the radionuclide-contaminated regions averaged about 8 mSv above natural background radiation, whereas the cumulative mean dose to those living in the ASCs was about fivefold greater, 42 mSv above natural background. Due to the combination of radioactive de-
cay and radionuclide migration, the radiation doses received during the first decade of exposure were about 60 percent of the total doses the inhabitants would receive if they continued to live in these areas for the remainder of their lives. Both the chapter and the Forum report agree that such total-body doses accumulated at very low dose rates over long periods of time are insufficient to induce significant radiation-related diseases or conditions.

Finally, both research reviews comment on the special case of localized irradiation of thyroid glands by Chernobyl accident-related radioiodine. Iodine-131 internalized by inhalation or ingestion was actively concentrated in the thyroid glands, especially in the glands of the children of families that were evacuated or who continued to reside in fallout-contaminated areas. A regional less-than-optimum nutritional level of non-radioactive iodine noted in the chapter was likely to have increased the efficiency of iodine-131 concentration. Beginning within four years of the Chernobyl accident, a very high incidence of childhood thyroid cancer developed. The chapter points out that the 2000 UNSCEAR Report to the UN estimated that approximately 1,800 such childhood thyroid cancers had been diagnosed. The Forum reports nine thyroid cancer deaths among such children, and a total of about 4,000 thyroid cancers. Their summary also cites data indicating that almost 99 percent of children with thyroid cancer have not died of the disease.

By analogy to the fates of the children who survived the A-bombs, my chapter interprets the absence of increased childhood leukemia in the presence of the increased iodine-131-related childhood thyroid cancer as evidence that their total-body radiation doses were insufficient to induce leukemia and, it seems likely, other cancers as well. Most of the parental evacuee generation probably received total-body radiation doses similar to their children’s doses. Children are more susceptible to radiation-initiated cancers than adults; hence, the chapter reasoned, their parents are not likely to develop high frequencies of radiation-related benign or malignant diseases.

The Forum concludes that, overall, about 4,000 radiation-related deaths may ultimately occur principally among the emergency workers, with some other relatively high death rates among the liquidators who received a high total-body radiation dose and perhaps some evacuees also. Indeed a few cases of adult leukemia of a type seen in irradiated populations have been observed among the emergency workers at appropriate time intervals. However, the Forum notes that approximately 25 percent of all deaths in Russia, Ukraine and Belarus are the results of cancers unrelated to radiation exposure. Hence the predicted about three percent increase in cancers resulting from Chernobyl accident-related irradiation may not be detectable.

Finally, the Forum review and the chapter agree that there are no indications that Cherno-
Chernobyl accident-related reductions in fertility have occurred among liquidators or evacuees, nor have there been increases in congenital malformations among their progeny. Both documents recognize that depressed attitudes, unhealthy life-styles and continued anxieties have plagued many of the members of the groups discussed here. These negative influences probably have contributed to the constellations of adverse symptoms experienced by the Chernobyl populations independently of their radiation exposures, and have made it more difficult for them to live productive and satisfying lives.

References for Tables


Further Reading


Chapter Ten

THE ACCIDENTS AT THREE MILE ISLAND
AND CHERNOBYL(1)

Colleen F. Moore

Radioactivity is one of the most dreaded types of pollution (Slovic, 1987), and also one of the most controversial. Scientists have argued about how hazardous radiation is from the time it was discovered until the present. I am going to tackle this highly controversial topic by focusing on the effects of radioactivity from nuclear accidents, and the effects of the uncertainties of such situations on the psychological well-being of children and their families. We start our atomic journey quietly in Pennsylvania, U.S., and then proceed to the former Soviet Union.

The Nuclear Reactor Accident at Three Mile Island

What Happened

The Three Mile Island (TMI) nuclear power plant is located near Middletown, Pennsylvania, on the Susquehanna River, just a few miles south of the city of Harrisburg. Metropolitan Edison’s two reactors began producing electricity in 1974 and 1978. The second reactor had been running for only three months when, at about 4:00 in the morning on Wednesday, March 28, 1979, an accident occurred that created a release of radioactivity, and a partial melt down of the fuel core. At 7:30 a.m. a general emergency was declared because the radiation monitor in the stack...
vent set off the alarm. Radiation exceeded the maximum that the stack monitor could record during the early part of the accident. The Pennsylvania Bureau of Radiation Protection was not notified that radiation was detected off the plant grounds until 10 a.m. even though Metropolitan Edison’s field crews had found excess radiation on the west shore of the Susquehanna River at about 8:30 a.m. Kunkel School, approximately six miles to the west-northwest of the TMI reactors, had the highest radiation reading (13 mR per hour) at 11:30 a.m. on the first day of the accident (Gerusky, 1981).

At the same time that radiation readings were being taken around the local area, Metropolitan Edison officials held a press conference assuring the public that there was no danger (Houts et al., 1988). From the citizen’s perspective the events of that Wednesday did not seem alarming. But conflicting reports began to emerge. At 4:00 p.m. the mayor of Middletown was told that a slight radiation release had occurred. The mayor appeared in public with a Geiger counter to double check the radiation readings being taken by staff. The mayor of Goldsboro, a town just one and one-half miles to the west of the plant, went door to door talking with people about the possibility of an evacuation (Trunk & Trunk, 1981).

Meanwhile “the radiation releases from the plant continued” (Gerusky, 1981, p. 55). The U.S. Department of Energy sent a helicopter to sample the air in the vicinity of the plant. By Thursday morning, March 29, the TMI accident had become a major media event. Governor Thornburgh’s press conference that day emphasized that there was no danger to the public (Houts et al., 1981). At 8:00 a.m. on Friday the radiation in the stack vent rose unexpectedly. This led some Nuclear Regulatory Commission members in Washington to recommend an evacuation (Houts et al., 1981). But it was not until shortly after noon on Friday, March 30, over 48 hours after the accident began, that Governor Thornburgh recommended that pregnant women or those with preschool children evacuate the area within five miles of the nuclear plant. Hydrogen had built up inside the plant, and there was a chance that the hydrogen would explode again in the worst case, perhaps breaking the containment building and spreading larger amounts of radiation. After the evacuation advisory, many communities sounded their emergency sirens (Houts et al., 1981). In the event of looting of evacuated homes, the mayor of Middletown had issued a “shoot to kill” order to police, adding the feeling of a state of siege. (Trunk & Trunk, 1981).

More than 60 percent of those within five miles of the plant evacuated, and more than three-quarters of those with preschool children left town (Dohrenwend et al., 1981). Families were sometimes divided in their opinions about evacuating, creating added stress (Flynn, 1988). By March 31st, the hydrogen inside the plant had dissipated. On Sunday April 1st, President
Jimmy Carter and his wife Rosalynn toured the damaged reactor. But most schools within five miles of the plant remained closed for the following week. The advisory to evacuate was lifted on April 9th (Houts et al., 1981).

How much radiation was released? After the TMI accident it was estimated that 13 to 17 curies of radioactive iodine were released (Mynatt, 1982). (For comparison, the Chernobyl accident released approximately 7 million curies of radioactive iodine (Ginzburg & Reis, 1991).) Health officials try to keep a close eye on radioactive iodine because it readily enters the food chain, can be passed by cows in their milk, and consumed by children (as well as adults) where it can damage their thyroids. Radioactive iodine was found to be higher in the thyroids of wild meadow voles trapped about a mile from the TMI plant compared to those captured about eight miles away in early April (Field et al., 1981). This finding met with controversy (Kirk, 1983; Field et al., 1983).

The TMI accident also released a plume of radioactive xenon (half-life of about five days) and krypton (half-life of over ten years) gases that are estimated to have contained 2.4 to 13 million curies of radiation (Mynatt, 1982). The initial radioactive plume was detected in the air 225 miles away in Albany, New York, on Thursday and Friday. The weather was “rather stagnant” the first day these radioactive gases were released, and so they would have remained in the area before being blown away as they decayed (Whalen et al., 1980). On Saturday, March 31st, the highest radiation reading of 38 mR per hour was recorded just to the northeast of the plant. At about the same time, the EPA began installing additional radiation dosage monitors (called TLDs, or thermoluminescence dosimeters) around the area, as did the Department of Energy, the Nuclear Regulatory Commission, and the U.S. Department of Health, Education, and Welfare. All these agencies deployed a total of 333 additional TLDs, but only 20 were present when the accident began (Gerusky, 1981). Only five TLDs were located in inhabited areas within five miles of the plant (Pasciak et al., 1981). Ten dosimeters were on the island occupied by the plant or on other nearby islands in the Susquehanna River. This implies that the radiation dosages in approximately a 19-square-mile area occupied by about 35,000 people had to be estimated from wind and weather conditions during the accident, five dosimeters, and the plant radiation detectors, some of which were off scale part of the time. Although radiation from the accident continued to be released unpredictably until April 4, the 333 extra dosimeters were not in place in time to be used in most dosage estimates.

In government reports issued soon after the accident, the average exposure was estimated to be between 20 and 70 mrem for people on the east bank of the river, and less than 20 mrem to others living within two miles of the plant (Fabrikant, 1979). There were many problems in
estimating dosages—the dosimeters did not record beta radioactivity, the wind and weather records did not allow the scientists to predict where the plume of radioactivity came near the earth, the exhaust stack release rate was never directly measured, and radioactive gases such as xenon and krypton were not directly measured (Fabrikant, 1979).

**Controversy Continues Over the Health Effects**

Whether the radiation from the accident was enough to cause health problems remains controversial. This book is centered on the psychological effects of pollution, whether those effects result from exposures that are directly toxic to the biological substrates of psychological functioning or result from indirect effects. Before turning to the psychological effects, I give a brief synopsis of the controversy over cancer in the TMI area.

Official pronouncements soon after the TMI accident estimated that the likelihood that radiation had caused immediate health effects was virtually nil, and that in the long term “its potential carcinogenic, mutagenic, and teratogenic effects combined add up to only about a one-in-a-million risk of death” (Upton, 1981, p. 69). Jacob Fabrikant, the Director of the Public Health Safety Task Force of the President’s Commission on the Accident at Three Mile Island, wrote that: “. . . we can conclude, therefore, that since the total amount of radioactivity released during the nuclear reactor accident at Three Mile Island was so small, and the total population exposed so limited, that there may be no additional detectable cancers resulting from the radiation” (Fabrikant, 1981, p. 156). For reproductive effects Fabrikant (1981, p. 157) said: “We can conclude, therefore, that no case of developmental abnormality can be expected to occur in a newborn child as a result of radiation exposure of a pregnant woman from the accident at Three Mile Island.”

Some residents testified in sworn statements after the accident that they experienced symptoms consistent with radiation poisoning, such as red skin, hair loss, and vomiting, and also testified that pets had died (Wing et al., 1997a, 1997b). There were also reports that cows nearby died unexpectedly (Bodansky, 1980), as well as miscarriages by farm animals. Farm animal deaths were not investigated as systematically as would be desirable (Wasserman & Solomon, 1982). Some residents attributed apparently sudden deaths of trees to radiation. In court, plaintiffs brought in a former Soviet scientist who testified that killed trees appeared very similar to radiation-killed trees in areas of the former Soviet Union where radiation releases had occurred (Rambo, 1996). The court ruled that plaintiffs had not provided sufficient evidence that the TMI radiation releases were causally related to their illnesses (Rambo, 1996; see Shrader-Frechette, 1987 for a discussion of ethical issues related to probabilistic harm).

As the result of settlement of an earlier lawsuit, a health monitoring program had been
funded by the utility company. Researchers have found that there is an increase in all cancers, lung cancer, and leukemia in the area. The scientific controversy is over whether the amount of radiation exposure could be responsible for the increased cancer, or whether the results are attributable to factors such as stress, or other confounding variables (Berg, 1997; Hatch et al., 1991; Hatch et al., 1997; Susser, 1997; Talbott et al., 2000a, 2000b; Wing et al., 1997a; Wing & Richardson, 2000). One group of researchers interpreted the data as showing that, “Overall, the pattern of results does not provide convincing evidence that radiation releases from the Three Mile Island nuclear facility influenced cancer risk during the limited period of follow-up” (Hatch et al., 1997, p. 12). Using the same data, another set of researchers drew the conclusion that, “. . . cancer incidence . . . increased more following the TMI accident in areas estimated to have been in the pathway of the radioactive plumes than in other areas . . . Causal interpretation is further strengthened by the observation that . . . higher and lower dose study tracts are all within 10 miles of the source and differ in exposure only as a function of weather conditions at the time of the accident” (Wing et al., 1997a, pp. 56-57). Biases in the interpretation of results have been implied in the commentaries (Susser, 1997; Wing et al., 1998). The reanalysis of the data by Wing et al. (1997a) was funded by a grant to the University of North Carolina from attorneys for approximately 2000 TMI area residents suing for damages (Wing et al., 1997b). The original data collection was funded by money from the utility company administered by the court.

More follow-up data are being collected on the cancer incidence and mortality at TMI. Unless the results are unequivocal (an outcome that is exceedingly unlikely), the controversy is likely to continue: “Despite a century of research since Roentgen’s discovery of X-rays, fundamental disagreements exist over biophysical mechanisms, dose-response assumptions, analytical strategies, interspecies extrapolations, and the representativeness of studies of select human populations” (Wing et al., 1997b).

In the research on disasters involving radioactivity, the retrospective dosage reconstructions are sometimes interpreted as if they were direct measures of individual exposure. The absolute estimated exposure values are often used to decide whether obtained differences in disease or psychological functioning should be attributed to the effects of radiation or not (see Hatch et al., 1997; Wing et al., 1997b; Wing & Richardson, 2000; Talbott et al., 2000a, 2000b).

Let me make an analogy to lead exposure. Suppose that a researcher studied children in an area in which leaded gasoline is used. Using data on dispersion of air pollutants from major highways, suppose the researcher also constructed a model of how much lead exposure was received by children living at different distances from the highways. These estimates from the
model are then used as if they were measures of lead exposure. Suppose that after finding a significant relationship between estimated lead exposure and IQ scores (including appropriate confounding variables), the researcher concluded that the lower IQ scores cannot be attributed to lead because the estimated lead exposures were too low to affect IQ. This is analogous to the TMI research in which estimated exposures from a model of air flow are said to be too low to be responsible for illnesses. The assumption about how much exposure is needed to yield a particular effect is being given primacy over an association between relative exposure and outcomes.

The Psychological Impacts of the TMI Accident

In contrast to the official estimates that there would likely be no detectable increase in cancer or birth defects among people living close to TMI, the effects of stress on psychological well-being have been readily acknowledged. A central point I have made repeatedly is that the psychological effects of pollution are real effects that impact our daily lives enormously. This was certainly true of the TMI accident.

Technological failures pose unique psychological problems because they involve a loss of societal control and a loss of trust in authority and experts (see Baum & Fleming, 1993, for an overview of the special challenges that face people coping with technological accidents). People who lived close to TMI went through a disturbing crisis in which accurate information was unavailable (Flynn, 1988). Not only was there the risk of exposure to radioactivity in uncertain quantities, but there was the trauma and stress of temporary evacuation, uncertainty of the outcome of the crisis, and uncertainty about how much exposure to radiation from the accident had already occurred.

The consensus among social scientists is that this very stressful event had relatively long-lasting consequences for psychological well-being (Baum et al., 1983; Bromet et al., 1990; Dohrenwend et al., 1981). Research showed that people from the TMI area fared worse than comparison groups on measures of stress and emotional functioning almost five years after the accident (Bromet et al., 1990). It is important to keep in mind that the possibilities of evacuation and exposure to uncertain quantities of radiation are inherent in nuclear power. Wherever there is a nuclear power plant, there must be an evacuation plan and a radiation monitoring program. The potential for evacuation and the psychological impacts of an accident or other incident should be incorporated in the social impact sections of environmental impact reports. As a result of the TMI incident, social scientists know more about those impacts than before the acci-
Mothers with Preschool Children

Mothers with preschool children experienced the most stress of any demographic group. One researcher compared TMI mothers of preschool children to others near TMI, people living near a coal-fired electricity plant, or near a different nuclear plant (the Shippingport plant near Pittsburgh) (Bromet et al., 1990). The study assessed mental health, beliefs about whether the TMI plant was dangerous, and distance of residence from the plant. The assessments were done five times after the accident (9 months after, 1 year, 2 1/2 years, 3 1/2 years, and approximately 6 years later in 1985 when the plant was restarted).

As time passed, differences between mothers who did and did not believe that the plant was dangerous became greater. Three and a half years after the accident, mothers who thought TMI was a hazard had three times the risk of an episode of depression or anxiety during the previous year, compared to TMI mothers who did not believe the plant was dangerous. In contrast, plant workers had fewer long-term psychological adjustment problems than the mothers, and the workers’ problems disappeared after the first year (Dew et al., 1987). The authors concluded, “. . . the TMI accident has had a long-term adverse effect on the mental health of the mothers of young children, particularly those living within five miles of the plant when the accident occurred and those continuing to perceive TMI as dangerous years later” (Bromet et al., 1990, p. 58).

Research on fathers of preschool children at TMI was apparently not carried out. Studies of other kinds of disasters (floods and chemical pollution in Missouri) suggest that men and women often differ in their reactions. One study found that in both genders there was an increase in depression and somatic symptoms 11 months after a disaster compared to before, but that for males there was also an increase in alcohol abuse symptoms, and that these effects varied depending on how much social support was available from others. The researchers concluded that “. . . men are more adversely affected by personal exposure to disaster than are women. . . . Only when exposure [to disasters] is accompanied by heavy demands for nurturance--an obligation traditionally associated with the female role--does it have a negative impact on women’s mental health” (Solomon et al., 1987, pp. 1107-1108). Given these findings, it is unfortunate that fathers at TMI were not studied as thoroughly as the mothers.

Children and Youth at TMI
A study of teenagers (7th, 9th and 11th graders) approximately two months after the TMI accident asked them to think back to how they felt during the accident, and also to report their current state on several questionnaires. Girls remembered being more distressed than boys, and youth whose families evacuated remembered more psychological distress than those who did not evacuate. Teenagers with a preschool-aged sibling reported having experienced the most psychological distress of any of the subgroups. Two months after the accident, those teenagers with a preschool sibling still reported more psychological distress than others. In the 7th and 9th graders, there were more somatic symptoms (headaches, stomach aches, and so on) than in the older students (Dohrenwend et al., 1981).

Three and one-half years after the accident, researchers interviewed children 8 to 16 years old and their mothers—those who lived near the TMI plant, those with a parent employed at the TMI plant, those who lived near another nuclear plant, and those with a parent employed at the other plant (Bromet et al., 1984). All the mothers completed a questionnaire that assessed the children’s social competence, behavior problems, and the mother-child relationship. The children answered a fear survey, a self-esteem questionnaire, and were also interviewed about the TMI accident and knowledge of nuclear power. The results showed no significant differences among the four groups of children in how upset they were, although the averages were in the direction of the TMI children having slightly worse psychological adjustment.

More fine-grained analyses showed that how upset the TMI children were, or their mothers said the children were during the accident, was related to the children’s overall fearfulness 3 1/2 years later. These correlations accounted for a maximum of 10 percent of the differences among children in their fearfulness. Better mother-child support was related to better child self esteem, fewer behavior problems, and better social competence. The research team concluded that children adjust “well over time when faced with the stresses caused by . . . man-made events,” but that, “Children who initially were upset by the accident may continue to be more vigilant and unable to deny the situation’s severity . . .” (Bromet et al., 1984, p. 298).

I have included this study even though it is based on retrospective interviews with the children and their mothers because there is so little data on how children react to pollution disasters. As the researchers noted, the results of any retrospective study can be partly due to reporting bias—those children and mothers who are not doing as well could reconstruct the past to be consistent with their current functioning. Another issue is that the study compared the TMI children with children who lived near the Shippingport reactor, the first commercial reactor built in the U.S., perhaps underestimating the impacts of the accident on the children. The Shippingport plant had also been the subject of controversy, and hearings on a plan to build another reactor
Risk Perception, Stress, and Coping at TMI

The research on the aftermath of the TMI accident found that mothers of preschool children living within five miles of TMI had a higher likelihood of negative long-lasting effects on their psychological well-being than other adults; the problem was exacerbated among those who believed the plant was dangerous. How children adjust to most stresses is linked to how the rest of the family reacts (Aptekar & Boore, 1990). Because of this, it is important to look at how the adults coped with the crisis at TMI and its aftermath. Also, the same general principles of stress and coping seem to apply to children under stress, depending on how old they are and how much they can understand about a situation.

Risk Perception or Threat Appraisal

If you do not regard a situation as threatening, then until you realize that you have been harmed in some way, you will not be stressed. On the other hand, if you think something has potential to harm you seriously enough, then you will not only be fearful, but you are also likely to take steps to avoid the event if you can.

At TMI, risk perceptions were relatively stable over a follow-up period of 3.5 years (Dew et al., 1987; Goldsteen et al., 1989). Six months after the accident, those who perceived the danger to be higher also showed higher psychological distress. Three and a half years after the accident, perceived harm to health was still significantly related to psychological distress symptoms (Goldsteen et al., 1989). The TMI mothers who believed the power plant was dangerous were
more likely to show depression or anxiety 3.5 years after the accident than those who did not perceive the plant to be dangerous (Bromet et al., 1990).

**Two coping styles**

Perception of a threat calls for coping. Problem-focused coping centers on action: pack your things and get ready to evacuate your family, plan what highway to take, make arrangements to stay with friends in another city, start a citizen advocacy group, and so on. In contrast, emotion-focused coping is oriented toward fixing our feelings, not the world around us: focus on positive aspects of the situation, make jokes, seek comfort by talking with someone you feel close to, drink or take drugs, exercise or play games, participate in religious services or rituals, and so on. Good coping involves both problem and emotion focused strategies (Kleinke, 1991; Lazarus & Folkman, 1984).

At TMI a research team from the Uniformed Services University of the Health Sciences (a part of the U.S. military, in Bethesda, Maryland) found that emotion-oriented coping was more effective than problem-oriented coping. Those residents who reported the least emotion-oriented-coping were also likely to report more depression and more symptoms of psychological distress than those who were high in emotion-coping. Those highest in problem-oriented coping, however, reported the highest levels of depressed affect and more symptoms of distress. Measures of stress-related hormones in urine (norepinephrine) also showed that the TMI residents with high problem-oriented coping were the most stressed (Baum et al., 1983).

One possible reason that problem-oriented coping did not reduce stress at TMI may be simply that people were unable to alter the situation. This would be true for many kinds of pollution. For example, calling to complain about a smelly factory (Cavalini et al., 1991) or a noisy airport is problem-oriented coping, but it is very unlikely to reduce the odor or noise. Another interpretation is that people who report high problem-oriented coping might actually be experiencing more negative effects than others. A more severe pollution event is also more likely to require problem-oriented coping, and the psychological effects of more severe events are less likely to be able to be dealt with by emotion-oriented coping strategies alone. Suppose you or one of your relatives were accidentally exposed to enough radiation that your skin turned red, or your hair fell out later, as some people at TMI testified in sworn affidavits (Wing et al., 1997a). You might adopt a predominantly problem-oriented coping style: write a letter to the company requesting medical expenses, talk to an attorney, discuss options for action with neighbors who had similar experiences, and so on. While you are doing all this, you could also adopt emotion-focused coping strategies of various sorts. Doing these kinds of things about a pollution prob-
lem can solidify a person’s belief that the problem is a health risk. Then because the risk is not only actually more serious, but also is viewed as more serious, a person may feel even more psychological distress from exposure. Regardless of why, at TMI problem-oriented coping was associated with higher psychological distress (Baum et al., 1983).

**Perceived controllability and blame**

When people think that they have no control over events that are important to their lives, it can decrease their motivation and increase negative emotions about themselves and life in general (see Seligman, 1975 for the classic theory of ‘learned helplessness’; see Abramson et al., in press, for an overview of cognitive theories of depression, and see Dweck, 1975, for the classic study of learned helplessness in children). The Uniformed University research team at TMI also assessed people’s overall beliefs about the controllability of life events (Davidson et al., 1982). More than a year after the TMI accident, while the accident clean-up operation was going on, the study compared people living close to TMI with people of similar socio-economic background who lived about eighty miles away in Maryland. The TMI residents who felt the least control over their lives showed higher somatic symptoms (such as digestive problems, nausea, headaches, and so on), higher anxiety, worse depressive feelings, and higher levels of the stress-related hormone norepinephrine than either the people from Maryland or TMI residents who felt more control over their lives (Davidson et al., 1982).

The Uniformed University researchers also examined how blaming was related to adjustment after the TMI crisis (Baum et al., 1983). TMI residents who said they blamed themselves in some way for their overall life situation showed better adjustment than those who took no personal responsibility. Lower self-blame was associated with more somatic symptoms, more depression, and slightly higher stress-related hormones (norepinephrine). The Uniformed University authors concluded that “... some assumption of personal responsibility for problems created by a technological accident or mishap is associated with resistance to stress-related difficulties” (Baum et al., 1983, p. 134).

These findings on self-blame are a bit surprising because the TMI accident was clearly the responsibility of the utility company and its employees, not the public. But blaming others often entails anger and chronic anger is related to higher chronic stress levels. Blame is also a term with moral connotations that often calls for censure, punishment, and reparation. Injustices normally provoke anger in victims, producing a double injustice—the unjust situation itself plus the anger and stress caused by having been wronged.

**Summary of Stress Aftereffects of TMI**
People near TMI at the time of the accident experienced both acute and chronic stress. The long-term effects on psychological well-being depended on whether a person lived within five miles of the accident site, other characteristics of the individual, the family, the person’s beliefs, attitudes, and coping strategies. Worse psychological adjustment years later was associated with living in the five-mile evacuation zone, being a mother or teenage sibling of a preschool child, believing the plant was dangerous, being high in problem-orienting coping and low in emotion-oriented coping, feeling the situation is not personally controllable, and blaming others.

Do these findings imply that the effects of TMI are “all in the head”? It may be tempting to say that those who suffered long-term psychological effects of the stress of the TMI accident should just “pull up their socks and get on with life.” To the person living through the crisis and its aftermath, the psychological effects are as real as cancer, and psychological functioning is not simply controllable by will power and volition. Psychological stress is also linked to physical health. High noise is related to higher blood pressure. Other evidence shows that immune system functioning and inflammatory processes are influenced by psychological stress (see Kiecolt-Glaser et al., 2002, for an overview).

Are Public Risk Perceptions Irrational?

Risk perception is nearly always the dividing line between advocates and opponents of nuclear power. One argument is that TMI created long-term stress because some people had incorrect perceptions of the risks of nuclear power and the accident. According to this argument, people would not have been so upset if they had known more about the risks of nuclear power and low level radiation.

Public understanding of nuclear power and radiation could certainly be improved, but scientists have disputed the short and long-term safety of radioactivity since it was discovered. Sometimes what was initially thought to be safe was later found to be harmful. For example, women were sometimes x-rayed during the last trimester of pregnancy to ascertain the position of the fetus (Spelt, 1948), or for other obstetric reasons. In 1958 Dr. Alice Stewart and her colleagues in Britain published an article linking an increased incidence of childhood cancer to prenatal x-rays (Stewart et al., 1958). Conflicts among scientists regarding the safety of nuclear power escalated in the late 1960s when John Gofman, Arthur Tamplin, and Ernest Sternglass, scientists who worked in the nuclear industry, published papers claiming that the routine releases of radioactivity from nuclear power plants were hazardous (see Hohenemser et al., 1977 for an overview of some aspects of the controversy among scientists; Freeman, 1981, contains
Many scientists took sides. In 1977 before the TMI accident, one scientist wrote, “Evidence of the escalating conflict over nuclear energy policy is particularly abundant in the scientific community . . . A leading journal recently rejected an article by nuclear critics because of its advocacy tone and later accepted one by a proponent of nuclear power, which provoked a stinging rebuttal” (Hohenemser, 1977, p. 33; see also Freudenburg, 1988 and Slovic et al., 1991 for overviews of some of the disputed aspects of nuclear risk assessments and risk perceptions).

Much more is known about the risks of exposure to low-level radioactivity now, but the state of knowledge and lack of knowledge about long-term effects preclude either side in the dispute from claiming to have “the answer” (see Clarke, 1999; Fairlie & Sumner, 2000; Koblinger, 2000, de Brouwer & Lagasse, 2001 for discussions of low level radiation policies; see Birchard, 1999 for a summary of one policy argument over thresholds). The National Academy of Sciences Committee on the Biological Effects of Ionizing Radiations (called BEIR) issues reports on radiation hazards at least every decade. Newer reports usually estimate either a higher probability of damaging effects or a lower dosage for damage than do older reports. For example, BEIR V said, “The frequency of severe mental retardation in Japanese A-bomb survivors exposed at 8-15 weeks of gestational age has been found to increase more steeply with dose than was expected at the time of the BEIR III report” (NAS, 1990, p. 7).

Would improving public knowledge of nuclear power make public attitudes more positive? In the 1970s, approximately 80,000 people in Sweden participated in a project to increase knowledge about energy options. People met in small groups for a total of at least ten hours. After participating in the educational program, the attitudes of the participants still indicated serious concerns about the safety of nuclear power, and the proportion of people who were undecided increased to almost three-quarters. In the following year, the pro-nuclear power Social Democratic government was defeated in elections. The defeat was regarded as due to dissatisfaction with the party’s nuclear program. (Nelkin, 1977, pp. 61-65). The outcomes of the Swedish educational program suggest that risk perception and knowledge are not directly related, as has been found in other research on risk perception (Davidson & Freudenburg, 1996).

The Nuclear Reactor Accident at Chornobyl, Ukraine (former U.S.S.R.)
What Happened

The Chernobyl (4) nuclear power complex included four reactors located about 80 kilometers (50 miles) from Kiev, Ukraine, approximately where the Pripyat River meets the Dnieper River (see map in Figure 2.) On the night of April 25 to 26, 1986, the Number 4 reactor went out of control. Two explosions occurred that blew the top off the reactor and the roof of the building. The reactor caught fire and continued to smolder until May 6. The accident “spilled radiation over 160,000 square miles in Belarus, the Russian Federation and the Ukraine” (United Nations, 2002). The Soviet government issued no information about the accident for 35 hours. In Pripyat, a city of 50,000 nearest the reactor, children played outside, schools stayed open, and people continued their regular activities, even as rumors of the reactor accident and radiation spread. The first radio announcement in Pripyat said that people would be evacuated for three days, and should take only two bags and light clothes with them. The evacuation turned out to be permanent. Meantime, in Kiev, which also received some fallout, thousands of children marched in the May Day parade (Marples, 1988).

A 30-km (18-mile) ring around the Chernobyl reactor was evacuated. The United Nations 15-year report estimated that the evacuation total was approximately 116,000 people (UNSCEAR, 2001b), but children who were eventually evacuated from regions in Belarus, and temporarily from Kiev, are not included in that number (Marples, 1988). David Marples, a Canadian scholar of the Soviet Union, estimated the total number of people at least temporarily evacuated was about half a million (Marples, 1988, p. 31) and that almost a quarter million were permanently relocated (Marples, 1997). Marples’s estimate of the number permanently relocated agrees with the U.N.’s 15-year report.

The trauma of the initial evacuation of Pripyat can be appreciated from an eyewitness who worked at helping coordinate the evacuation: “The fact is that there was no evacuation scheme, and we did not know in which villages were which Pripyat buildings or microrayons . . . who went where? In Poliske we had a list of children. So I would phone the Village Council and ask: ‘Do you have such and such parents? Their children are looking for them.’ And they could say to me: ‘We have such and such children who are without parents. Generally, we do not know where these children are from.’ You sit and phone all the Village councils (Shcherbak, 1989, p. 70).

Another participant in the evacuation remembered it this way: “Most people did what they were told and didn’t even take spare money with them. When the time came, we went straight from the entrance [of the apartment building] and boarded the buses . . . We were driven to Ivankov, 37 miles from Pripyat, and then to various villages . . . Many of those who were de-
posited in Ivankov went farther, toward Kiev, on foot; some of them hitchhiked, with no idea of what they expected to find. Some time later, a helicopter pilot I know told me that he had seen, from the air, enormous crowds of lightly-clad people, women and children, and old people walking along the road, and on the side of the road, in the direction of Kiev. They had already reached Irpeni and Brovarov. Cars were stuck in the midst of these crowds, as if they were among vast herds of cattle being driven to pasture . . . And the crowds of people kept on walking, endlessly” (Medvedev, 1989, pp. 187-188).

Those assisting at the checkpoints in the 30-km zone worked exceedingly long hours measuring the radiation on people, and receiving radiation exposure themselves. Here is the report of a medical student who worked both at a checkpoint, and in the hospital treating radiation victims: “[At the checkpoint] the people got out of the bus, stood in a line . . . There was one case where one grandad’s boots were ‘radiating’ a great deal. ‘But I’ve washed my boots, lads,’ he said. ‘Off you go, Grandad, you’ve got to shake some more off.’ . . . We sent him to wash three or four times . . . We caught a lot of really dirty [radioactive] trailers, with dust-covered things. We sent them off to be washed . . . I remembered a Belarus tractor. In the cabin next to the driver was an old man, his father perhaps. The old man was carrying a hen and a dog. And he said, ‘Measure my dog.’ I said: ‘Grandad, shake your dog’s hair well when you get to your destination.’ . . . Around 11-12 May I noticed that I was sleeping a great deal but not feeling refreshed . . . A blood analysis was done and I was put on the eighth floor in our department [where those with radiation sickness were being treated]” (Shcherbak, 1989, pp. 86-87).

The evacuation spawned its own controversies. First, the evacuation was delayed, and in the interim, no information to protect people was given. Some nurses voluntarily went door to door handing out potassium iodide to protect people from radioactive iodine. Second, the upper echelon party members and workers who could be used in other nuclear plants were evacuated before others. Third, many people from Pripyat were evacuated to Poliske, to the west, which later had to be evacuated because of radioactivity. Fourth, children were not evacuated from any parts of the 30-km zone except Pripyat until May 21, nearly a month after the accident. (Marples, 1988). Finally, an ongoing controversy is that some Russian scholars believe it was not necessary to evacuate people from some areas because radiation in those areas was lower than “background” radiation in other areas (Filyushkin, 1996). Radiation hot spots continued to be discovered as late as 1994 when 1000 square kilometers (about 370 square miles) were declared contaminated. People in those contaminated areas did not necessarily relocate because they are reluctant to move unless they can get jobs elsewhere, and they do not want to leave home (Marples, 1997).
The government was probably hoping to re-open the evacuated areas. But in the interim since the accident, not many evacuated villages have been declared habitable. Approximately 20 percent of land in Belarus has been removed from cultivation. It is estimated that in order to decrease the radioactivity by 50 percent, it will take until approximately 2020, and then it will take another 300 years for a 70 percent reduction. Radioactivity will continue for approximately 100,000 years from the very long-lived isotopes, such as plutonium (Marples, 1996; see also UNSCEAR, 2001b, for maps of the polluted areas).

Radiation Casualties, ‘Liquidators,’ and Environment

Another controversy concerns the number of victims. Official Soviet sources said that 31 people died, two from the reactor explosion and 29 from radiation sickness. The men who died were mainly firefighters who struggled heroically to contain the blaze. The Soviets said that 299 people were treated for radiation sickness. A U.S. physician who helped with bone marrow transplants estimated that about 500 people being treated for radiation sickness. A former Soviet engineer and human rights activist reported that 15,000 people had died in hospitals in Kiev in the five months following the accident, and that other diagnoses were used to mask radiation sickness. The Soviet government claimed that “Not a single case of radiation sickness had occurred among the population . . . around the nuclear plant” (Marples, 1988, p. 36).

Hundreds of thousands of Soviet soldiers were sent in to help put out the fire, rapidly construct a cement containment building around the burned-out reactor, relocate the public, and clean up radioactive debris in the power station and the surrounding area. The exact number of these “liquidators” is unknown but is as high as 600,000 (UNSCEAR, 2001b). Their radiation exposure is also mostly unknown. Marples wrote that, “. . . any estimate of direct casualties involves supposition and guesswork . . . Even ‘official’ sources are wildly inconsistent--how can one reconcile statements from Ukraine’s health ministry and the Chernobyl Union that thousands of union members have died--with an official report from Belarus that only 150 of the 66,000 decontamination workers from that republic have died?” (Marples, 1996, p. 23). Marples (1996) concluded that approximately 6000 deaths in the immediate aftermath of the accident “represents the minimum possible number.”

Effects on Children’s Psychological Development
There are at least two reasons to expect that prenatal exposure to radiation would affect children’s intellectual development. First, if the pregnant mother and fetus are exposed to enough radioactive iodine to affect thyroid function, lowered thyroid function can affect the cognitive development of the child. Second, prenatal exposure to ionizing radiation is recognized to be one cause of mental retardation. For the Japanese atom bomb survivors, as the estimated fetal radiation dose increased the likelihood of children being born with severe mental retardation increased, especially for radiation between the 8th and 25th week of gestation (Otake & Schull, 1998; Schull et al., 1990; Yamazaki & Schull, 1990). In addition, as estimated fetal radiation increased, the children’s IQ scores and school performance also decreased on average (Otake & Schull, 1998).

The Minsk study
A group of researchers in Minsk, Belarus, gave IQ tests to children whose mothers were pregnant at the time of the accident and living in an area of Belarus that was radiation contaminated (Kolominsky et al., 1999). The children were compared to children selected to be comparable in socioeconomic background, but who were living in a part of Belarus that did not receive fallout from the reactor accident. The exposed children and their families had also been relocated to the Minsk area when they were about five years old. Even though the sample size was relatively small (138 exposed and 122 unexposed), fewer exposed than unexposed children scored average or higher, and more exposed children scored in the range of borderline mental retardation (IQ score 70 to 79). The differences between the groups were smaller when they were re-tested at age 10, but the average IQ score of the radiation exposed group (93.7) was still significantly lower than the average IQ score of the of the unexposed group (96.1). There was not a significant relationship between IQ score and week of gestation at which exposure occurred. Estimated thyroid radiation dose showed a weak relationship to IQ test scores at both ages (accounting for approximately 3 percent of the differences among children in IQ score). The correlation between estimated thyroid radiation dose and IQ score just missed the statistical cutoff of $p = .05$ or 5 in 100.

The Minsk team also assessed the children’s psychological well-being with a psychiatric interview, a neurological exam, and assessed the parents’ anxiety with a questionnaire. The exposed children differed from the unexposed children in the frequency of speech, language, and emotional disorders at both testings (6-7 and 10-11 years of age). The emotional disorders in the exposed group were mostly phobias. Nine of the exposed children imagined “The Radiation as a cruel monster that could kill them or their parents” (Kolominsky et al., 1999, p. 302).
parents of the exposed children were more likely to score higher on trait anxiety, and parent anxiety was related to the presence of emotional disorders in the children. Fathers’ anxiety accounted for approximately 25 percent of the differences among children in emotional disorders. These differences in emotional adjustment of the parents years after the accident are reminiscent of the mothers of preschool children at Three Mile Island.

Because there was not a significant relationship between the estimated thyroid doses and IQ test scores, the researchers concluded that the stress of the Chernobyl accident and the social disruption of relocation and resettlement were important aspects of the negative effects seen on the children. Based on the relationship between parental anxiety and child emotional disorders, the research team speculated that high anxiety in the parents can have repercussions on family relationships which, in turn, can lead to emotional disorders in the children.

The Ukrainian study
A similar study was carried out with 6- to 8-year-old Ukrainian children, but the sample size is considerably larger (544 prenatally exposed children, and 759 children from a ‘clean’ region of the Ukraine) (Nyagu et al., 1998). The children were born between April 26, 1986 and February 26, 1987. Some of the exposed children were evacuated from the 30-km zone (N = 115), but the rest had been living in areas that were contaminated to varying degrees. The results were very similar to the findings of the Minsk team for two tests of non-verbal intelligence (the Draw-a-Man test, and Raven matrices), and a test of verbal intelligence (the British Picture Vocabulary Scale, translated into Ukrainian). As in the Minsk study, there were more exposed children in the lower IQ groups, and fewer exposed children in the top IQ score groups compared to the unexposed children.

When the children were 9-10 years old, a subset (50 exposed and 50 unexposed) were given IQ tests again, a psychiatric interview and an EEG (brain wave) test. The exposed children showed a higher likelihood of speech and language disorders, motor disorders, emotional disorders, and hyperactivity than the unexposed children. The EEG tests also showed some differences between groups—beta-power and beta-power were higher, and theta-power was decreased in the left hemisphere of the radiation victims compared to the control children. The Chernobyl children also showed greater lateralization of beta-power (Nyagu et al., 1998).

The authors of this study said that all studies that have examined the “mental health of the prenatally-irradiated children as a result of the Chernobyl disaster . . . came to the conclusion that the prevalence rate of disorders of psychological development, emotional and behavior disorders, as well as mental retardation, is higher in children irradiated in utero as compared to the
non-exposed children” (Nyagu et al., 1998, p. 309). Because they found EEG differences between the exposed children and the unexposed children, the Ukrainian research team favored the interpretation that radiation altered the pituitary-thyroid functioning of exposed children, which in turn has altered their neurological development and functioning.

**Similar results, different conclusions**

The Minsk and Ukrainian research teams found similar results, but drew different conclusions about the causes. The Ukrainian scientists favor the idea that radiation is directly responsible for the children’s difficulties, even though they acknowledge that the mothers’ verbal IQ test scores were slightly lower in the exposed sample than in the nonexposed sample, and that the exposed parents’ overall mental health was worse. In contrast, because estimated thyroid radiation dose was not related to the children’s IQ test scores, the researchers from Belarus drew the conclusion that the stress, social disruption of evacuation and relocation, as well as pre-existing differences in parental education levels, could account for the results. Notice that the Belarus researchers used estimated radiation exposure to interpret the rest of their results. Instead of questioning the accuracy of the retrospective radiation estimates, they discounted the role of radiation as a potential cause of the differences in the children’s functioning. Neither of the studies assessed parent education or income. However, in the Ukrainian study, the exposed children’s families had slightly nicer apartments on average than the comparison group (as judged by the number of rooms per person) and a slightly higher standard of living, factors that are generally associated with better performance, not worse.

**U.S.—Ukrainian Cooperative Study**

A research team from State University of New York at Stony Brook collaborated with a team of scientists in the Ukraine (Bromet et al., 2000; Litcher et al., 2000). One of the investigators, Dr. Evelyn Bromet, was also involved in the TMI studies of mothers and children. The exposed sample of 300 10- to 12-year olds was drawn from children who had been evacuated to Kyiv (Kiev), Ukraine, from more highly exposed areas, and who were either *in utero* at the time of the accident or less than 15 months old. Comparison children were drawn from the same classrooms as the exposed children.

The researchers administered a large battery of neuropsychological tests to assess the intellectual and behavioral functioning of the children and the psychological functioning of the mothers. The results showed that Chornobyl evacuee mothers reported that their children dis-
played more somatic symptoms, thought problems, and delinquent behaviors than the comparison sample. The evacuee children rated their own scholastic competence as worse, and had more anxiety focused on Chornobyl than the comparison children. Almost half of the evacuees were diagnosed with ‘vascular dystonia’ (6) compared to about one-seventh of the comparison children (Bromet et al., 2000). Mothers of evacuees also reported more memory problems in their children than did the comparison mothers (Litcher et al., 2000). The children with higher Chornobyl-focused anxiety also scored lower on three attention measures (Trails test, a word finding test, and teacher rating of attention). Children with higher overall anxiety were rated by their mothers as having more problems compared to children with lower anxiety (Litcher et al., 2000). There were no significant differences between exposed and non-exposed children on a nonverbal IQ test or other dimensions of the teacher rating scale.

Just as in the TMI study, the mothers of the Chornobyl evacuees showed higher somatization symptoms, expressed higher feelings of stress about Chornobyl and its potential health effects, and were more likely than the mothers of the comparison children to have had a depressive episode. Maternal health stress and rating of trauma due to the Chornobyl accident were correlated with the mother’s ratings of the child’s somatic symptoms (Bromet et al., 2000).

The authors concluded that “the present results provide no support for the presumption of cognitive or neuropsychological differences between the two groups of children” (Litcher et al., 2000, p. 298). For the children’s psychological functioning, the investigators concluded, “Although radiation and nuclear power evoke deeply rooted fear and anxiety in adults, our study found that 11 years after the explosion, the trauma was not transmitted to children who were unborn or infants when their families were resettled in Kyiv” (Bromet et al., 2000, p. 569). These conclusions were drawn in spite of finding a significant relationship between children’s Chornobyl anxiety and performance on three measures of attention. (7)

Studies of Adult Mental Health

A team of scientists from The Netherlands, Russia, and Belarus used several measures of mental health to compare people living in the relatively heavily polluted Gomel region of Belarus with a sample from Tver, Russia, an area not affected by Chornobyl fallout (Havenaar et al., 1997). Many evacuees and former liquidators live in the Gomel region. Gomel also received fallout, and some of the villages were evacuated, mostly involuntarily. Because the loss to cultivation of about 400,000 acres (625 square miles) has had a severe economic impact on the area, residents of the Gomel region are under a variety of stressors (Havenaar et al., 1996). The re-
Results of the mental health assessments showed that four years after the accident, people in the Gomel area rated their health to be worse, showed more psychological distress, and were more likely to have visited a doctor and taken medications recently (Havenaar et al., 1997). Six years after the accident, the same research team found that people in the Gomel region who were evacuated or who were mothers with children under 18 years of age were more likely to show psychological distress than other people in Gomel, regardless of the radioactive contamination in the area in which they were currently living (Havenaar et al., 1996).

In Israel, researchers have been tracking the psychological and physical well-being of immigrants from the Chornobyl area, as well as liquidators (Cwikel et al., 1997). They compared the Chornobyl victims with immigrants to Israel from other areas of the former Soviet Union, and stratified the sample into high and low radiation exposure groups. The liquidators and those who had been exposed to the highest radiation had a higher likelihood of post-traumatic stress symptoms when they were tested a year after emigrating to Israel. After another year, their symptoms had abated considerably. The same pattern held for depressive symptoms. For somatization (general health complaints), the most exposed group was higher than the unexposed group even two years later. The exposed groups differed from the comparison group in systolic blood pressure both one year and two years after emigrating. These scientists concluded that exposure to the combination of stress and radiation at Chornobyl was accompanied by psychological, physiological, and physical symptoms. The good news was that those symptoms tended to abate over the two year follow-up.

A French and Latvian research team studied the psychological well-being of a sample of over 1400 Latvian Chernobyl clean-up workers (Viel et al., 1997). The results showed a higher risk for mental and psychosomatic distress for those who worked on the clean up for four weeks or longer, cleared contaminated forest, or consumed locally grown fresh fruit, vegetables, or meat. These scientists concluded that working as a liquidator could increase psychosomatic disorders and psychological distress by any of three possible pathways: a) anxiety about radiation exposure could lead to psychological problems, b) radiation exposure could cause physical disorders, which in turn, causes psychological problems, and c) radiation could induce psychiatric problems directly. Finally, they note that “whether stress-related or radiation-induced, mental distress reflects a genuine human suffering to be taken account of and appears to be an important health consequence of the Chernobyl nuclear accident” (Viel et al., 1997, p. 1543).
Summary

The studies of children who were in utero or less than 15 months of age at the time of the Chernobyl accident show differences from comparison groups in psychological symptoms, and sometimes in IQ test scores. Reminiscent of the TMI mothers, the mothers of the Chernobyl children also show higher rates of psychological adjustment problems, including somatic symptoms and depressive episodes.

The U.S.-Ukrainian researchers commented that the Chernobyl victims underwent “harrowing experiences during the evacuation, arduous battles for residency permits in Kyiv and for government benefits, social stigma, and an irreversible loss of home, belongings, and lifestyle” (Bromet et al., 2000, p. 569). Eye witnesses reported that family members were often separated for some time during the evacuation (Medvedev, 1989; Shcherbak, 1989), and people faced discrimination in the communities in which they were resettled because they were regarded as carriers of radiation (Havenaar et al., 1996).

There are many alternative interpretations of the differences between the exposed samples and the comparison groups, including whether the comparison groups are equivalent enough in educational and economic background, “although some researchers believe that somatic and neurologic symptoms are psychogenic (psychologic) in origin, others claim that symptoms such as nervous system dysfunction, cognitive disorders, and pain may be the effect of low doses of radiation on the nervous system or the beginning stages of organic diseases” (Yevelson et al., 1997).

Whether radiation exposure could have direct effects on psychological well-being and neurobehavioral functioning has apparently not been well studied even in animal experiments. Studies of the effects of low-level radiation on animals have emphasized the effects of prenatal exposure and cancer or mutations as the main outcome variables, with behavioral effects neglected. There is one study of the neurobehavioral functioning of U.S. Gulf War veterans who have small pieces of shrapnel from depleted uranium bombs (8) embedded in them. The researchers found that the concentration of uranium excreted in urine was the best predictor of performance on a battery of computerized neuropsychologic tests (McDiarmid et al., 2000). The dose-response relationship bolsters the interpretation that exposure to uranium may affect neuropsychologic functioning. Whether the results are due to the biological properties of uranium as a metal, the small continuous doses of radiation, or the stress of recovering from injuries is not known. The results suggest the possibility that low level radioactivity might directly affect behavioral functioning, a possibility that merits further research.
Other Health Effects of the Chornobyl Accident

Summaries of the health effects of Chornobyl invariably include an increase in the incidence of thyroid cancer among those exposed during childhood (Bard et al., 1997; Holm, 2000; Lomat et al., 1997). Some claim that the leukemia rate is not elevated, even for the liquidators who were exposed to relatively high amounts of radiation (Holm, 2000). There are ongoing studies of leukemia rates in the liquidators but the radiation doses they received were not measured well (Balter, 1996). Some studies of workers in nuclear industries have shown higher rates of leukemia (Wing et al., 1991), and Japanese atom bomb survivors showed increases in leukemia within about ten years of the bombing (9) (see Preston, 1998, or Schull, 1995 for overviews). Two research groups have reported that hypothyroidism (under-active thyroid gland) is more frequent among people who were exposed to Chornobyl fallout than among other people from adjoining areas (Goldsmith et al., 1999; Pacini et al., 1999). Hypothyroidism affects physical and intellectual development in children, and so it is important that it be identified and treated.

Some studies of Chornobyl evacuees that have found increases in the rate of congenital malformations in embryos and fetuses, but the results may be due to overall declining nutrition and health care in the former Soviet Union countries. Details of methods are not always given in the publications, and so reviewers in Western countries tend to be skeptical (see Bard et al., 1997). Research with British nuclear workers has also shown a higher rate of miscarriages and stillbirths for offspring of male workers, although the results are controversial (Doyle et al., 2000; Doyle et al., 2001; Parker et al., 1999; Parker, 2001). In the research on Japanese atomic bomb survivors, a relationship between the radiation dose to both parents and the likelihood of any untoward pregnancy outcome (malformation, stillbirth, and early mortality) was not quite statistically significant. The authors of the Japanese study regarded their results as an underestimate of the effect of radiation on fetal loss and malformation and noted that “radiation has caused genetic damage in every species properly studied in an experimental setting” (Otake et al., 1990, p. 10). A higher rate of germline mutation compared to a sample in Britain was found in a genetic study of parents and children in the Mogilev area of Belarus, a locale that is high in radioactivity from the accident (Dubrova et al., 1996).

The summary of an international conference on the health effects of the Chornobyl accident reported that “There is no doubt that the incidence of thyroid cancer has substantially increased in children who were 0-18 years old at the time of the accident and that this is related to radiation from the accident” (UNSCEAR, 2001a, p.1). In the liquidators, solid tumors have increased in frequency, but the evidence for this so far is inconsistent. “Stable changes in chromosomes of somatic cells have been identified. Research is required to determine whether similar changes...
may lead to increased incidence of disease in offspring” (UNSCEAR, 2001a, p. 2). Cardiovascular, cerebrovascular, and thyroid diseases seem to be elevated in the liquidators, and these conditions may be related to radiation. Studies of the Japanese atom bomb survivors also showed increased cardiovascular disease, especially atherosclerosis (Zimbrick, 1998).

The report of the international congress also concluded that the main effects of the Chernobyl accident on the public appear to be cardiovascular and neuropsychological. The report listed these other health effects: decreased birth rate, worse health of newborns, increased pregnancy complications, and worse child health. The report concluded that health effects were likely exacerbated by declining economic conditions in the area, poor nutrition and food supply, the psychological stress of relocation, and continued residence in contaminated areas. (UNSCEAR, 2001a). The U.N. issued a report in February of 2002 calling for increased health services to the victims of Chernobyl, as well as “a long-term, well-funded research programme on the explosion’s environmental and health consequences” (United Nations, 2002).

**Endnotes**

1. This chapter is an excerpt from Moore’s chapter, “It isn’t fair: Environmental pollution disasters and community relocations” in her book, *Silent Scourge: Children, Pollution, and Why Scientists Disagree*, published by Oxford University Press in 2003. Used with permission of the publishers. Moore’s complete chapter also takes up other topics that are of interest to people concerned about the physical and mental health effects of environmental pollution, including the consequences of U.S. nuclear bomb testing in the Marshall Islands and Nevada, the after-effects of the released radiation at various European sites as well as at the U.S. sites employed for nuclear weapons development, and the consequences of the chemical pollution at the Love Canal in New York State.
Chapter Eleven

INFORMATION AS TRAUMATIC STRESSOR:
PSYCHO-SOCIAL AND PHYSICAL OUTCOMES OF TOXIC
AND TECHNOLOGICAL DISASTERS

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Anne Speckhard, adjunct associate professor of psychiatry at Georgetown University Medical School in Washington, as well as professor of psychology at Vesalius College, Free University of Brussels, specializes in the treatment of traumatic stress disorders. In addition to her private practice as a clinician and her teaching activities, she serves as a research consultant in the U.S. and Belgium, and has long been concerned with Chernobyl-related trauma issues.

The 21st century undoubtedly will have to cope with quite a few serious challenges posed by technological mishaps. The Chernobyl nuclear power plant explosion, which spewed long-lasting radiation well beyond the borders of the former Soviet Union, could well be a harbinger of other accidents to come. Although the Chernobyl incident taught the world dire lessons about the risks of nuclear power plant malfunctioning, and inspired new safety standards worldwide, the dangers of nuclear disaster remains with us. Indeed, this risk may even be on the rise if the widespread speculation about terrorist attacks on nuclear facilities has any validity.

The present chapter is largely concerned with a particular kind of technological disaster, one having to do with the spread of toxins over a large area. Havenaar (2001) defined such a technological disaster as an exposure of human beings to a hazardous substance in a defined place over a defined span of time due to some human error or action. The exposure may or may not be known at the time it occurs, but is recognized at some point, and harmful effects are attributed, whether accurately or not, to those who have been exposed to the toxins.

Any truly adequate preparation for technological disasters of this kind, especially if they
are as serious as the Chernobyl explosion, must be based on sound knowledge of how toxic disasters operate and threaten physical and psychological well-being. All of those with any major role to play—such as policy makers, public health officials, educators, and emergency and health care workers—must understand the ill effects arising from the information available to the populace, as well as from the spread of deadly and contaminating poisons. We will here examine the psychological and social mechanisms that operate to a considerable degree in toxic disasters, and will also consider ways of averting and alleviating the psychological distress and harmful mental health consequences that typically follow in the wake of technological calamities. I will also attempt to show that the fear of toxic contamination, whether it is realistically based on actual conditions or not, can be a new and challenging form of traumatic stressor.

Information as Stressor

Technological disasters have unique elements, many of which have been identified in the literature concerned with such events (Baum, 1983; Havenaar, 1997) that set them apart from other calamities. As an example, we rarely see in the former incidents the sudden and then quickly diminishing period of extensive destruction usually found in natural catastrophes. The damage sharply and dramatically done to a community or region by naturally occurring disasters is typically very clear and easily recognized, such as when an earthquake or fire claims a great many lives and destroys considerable property. This acute phase is followed by a relatively rapid diminution of the destructive force. By contrast, technological disasters often lack this sharply delineated destructive phase and whatever dangerous forces they produce are often unseen. Their traumatic aspects are frequently the result of frightening information (rather than the actual sight of the dangerous event), with this information usually being received over an extended time period, often with substantial delays. Hence, many authors note the crucial role played by information as the central stressor rather than a sensory experience of threat to life (Green et al, 1994).

The accident itself, apart from the contamination, may not be an acute stressor for the majority of those ultimately affected. Likewise, there may be a long time, in some cases years, between the actual incident and when the public develops a relatively high level of dread and anxiety regarding this hazard. For instance, in the Chernobyl disaster, relatively few persons witnessed the accident itself, compared to the thousands who were ultimately affected. Much of the distress following Chernobyl appeared well after the nuclear explosion and was manifested over an extended period of time as people learned of the accident and of the potential health
risks of radiation exposure, and as the seemingly related health problems emerged over time.

A Chernobyl victim recalls:

*Chernobyl will never be a joking matter for me. After the explosion, there was a holiday. It was a very warm and sunny day. At that time we did not know that there was danger. My daughter was pregnant. She went to the beach of the river in Kiev and sun bathed the entire day. This was probably the worst exposure she could have had. For now her son is okay, but as we see more and more cases of thyroid cancer in children from that time period, we worry about her son and what his health will be.*

Likewise, frightening information is often received in doses, sometimes with considerable delay after the accident, and in most cases, in fragmentary and contradictory ways. Because information involves perception and is applied personally, the acute phase of the disaster may occur in a highly personal manner as the toxic contamination is revealed in one’s own personal life.

A father who immigrated to the United States after Chernobyl discusses how the stress induced by the disaster reached its peak intensity for his family thirteen years after the nuclear explosion as a result of new terrifying information:

*We’ve just been through a really bad shock. Our son was born at the time of Chernobyl, a bad time to be born, but he was okay. He’s never had any health problems, nothing out of the ordinary. We sent him away with his mother during the bad times. They went to Russia until the contamination was under control, so I don’t think he got a high exposure to radiation. Then these past weeks my wife noticed his thyroid seems enlarged, he has a lump maybe. We took him to the doctors immediately and had him examined. They said he’s okay, that it’s nothing, just a lump. But I don’t know if I believe it. They don’t understand about Chernobyl here. They have never seen thyroid cancer like we had in Ukraine after Chernobyl. Do they really know what they are looking for? I thought we were through with these things. We live in America now, it’s in our past, but here it comes to us again. I haven’t slept for weeks I’ve been so sick with worry. Can you tell me the names of any really good doctors to take another look at him?*

Along with the long-term dread that over time pervades the community of those exposed, there is usually frustration over ambiguous information about the potential health consequences. It is often difficult even for well-intentioned and generally candid scientists to adequately predict risks arising from toxic exposure. Likewise, those affected by contamination often lose trust in those they deem responsible for the accident, and/or for those in charge of the clean up. Indeed, competing social concerns, neglect, questions of liability, and outright maliciousness may result in cover-ups, lies or delays in revealing the true extent of the problem. When trust in official channels is lost, contradictory and confusing information about the contamination often comes.
through non-official channels, creating confusion and alarm.

A British diplomat who lived in Russia at the time of the Chernobyl explosion comments on his frustration with both the Soviet and foreign press:

*I was living in Russia as a student when the Chernobyl disaster occurred. Immediately after the explosion there was no news from the Soviet government. The only news that was coming into the country was from foreign presses. But I was frustrated that the BBC was reporting off of other services and reporting it as a horrendous calamity affecting the health of thousands. The Soviet press was completely silent. It was an eerie feeling. We did not know whether to evacuate or not. When foreign students from Belarus were evacuated to Moscow, the foreign press followed them, expecting to see acute radiation sickness, which of course was not the case. It made me angry that they were not more responsible in their reporting. It created a climate of fear in Russia far away from the explosion that was not necessary. For days we couldn’t find out the truth and we did not know what to do.*

A Belarusian psychologist who observed the Soviet government’s failure to adequately warn their population after the Chernobyl explosion comments on how people started to make up their own stories about Chernobyl in the absence of information they could trust:

*The former USSR government decided not to tell anything about Chernobyl because they were afraid of panic and also because it was a Soviet tradition not to tell anything significant. They were afraid of losing control over the people. If they tell the truth they have to tell the truth in other cases as well. It is the way the soviet government functioned. Some educated people learned about Soviet actions from Western radio, but it was like a game. Crowds of people didn’t know anything. It seems to me that the Soviet government was in a phase of dissociation, they couldn’t accept the reality of what had happened and kept waiting for maybe the problem will solve itself. It is usual for our mentality. I think that people interpreted the behavior of authorities as cold because they were in stress and they need more warmth, they felt regressed and threatened and instead of support they received only the official stance. To solve their fears people rationalized. It is too difficult to fight against or even be afraid of something that you couldn’t see and control. So people created stories and fantasies about two-headed cats that were found near Brest and so on..*

A Belarusian diplomat relates a health-protecting rumor that many people followed:

*Before Chernobyl, we had Gorbochov trying to decrease alcoholism in the USSR. He had put strict controls on vodka. But after Chernobyl, the rumor began circulating that the nuclear submariners drank red wine and that it was a protection from radiation.*
Suddenly the streets were awash in red wine, and everyone began drinking it hoping that it would protect them from radiation.

Another woman recalls how there was confusion about iodine being protective against radioactive damage to the thyroid gland:

You know our government failed to give us iodine tablets right after the explosion. When people heard about it, it was already too late, but people did not understand this. They didn’t have iodine tablets but they knew that iodine was supposed to protect the thyroid. So they took antiseptic iodine and swabbed it across their throats, making a huge mark across their necks. It was so stupid, but they believed it would protect them. These were fairly educated people doing this. You know the radioactive iodide was already gone by that time. Its half-life is only fourteen days. So it was pure stupidity.

Information Processing with Toxic Traumas

Those who work with trauma victims know that individuals under severe threat do not employ their usual modes of information processing. An acute fear state causes people to narrow their focus of attention to the perceived source of their fear, as well as to potential means of escaping from the hazard, ignoring other matters. Later, if the fear state is retriggered, the emotional and cognitive sets that were present at the time of the trauma often return, and it may be difficult for the victims to enlarge their perspective until their reawakened fears are calmed. As a consequence, individuals whose beliefs are based on their alarming experiences may well continue collecting and concentrating on information that confirms what they had thought at the time of these occurrences, especially when memory of these frightening events comes to mind.

Those who deal with toxic disasters—officials, health workers, politicians, and the public at large—should understand that attitudes formed early on in the disaster situation are often very difficult to change, and that once strong fear has been aroused attention is often focused on the danger and not easily diverted to other details. Thus, those who report on a disaster, or who make official statements about it, must do so carefully. In an interview I had with Robert Frank, this journalist observes how the news media can be instrumental in shaping attitudes that are later difficult to change:

“People who are in a crisis generally recall and form their attitudes from the peak moment, the peak intensity, with far less attention paid to the more accurate picture that emerges over time. It has terrible effect on those people who are the object of the coverage, these intense moments. There is a predisposition to think a certain way before the facts are fully presented and afterward
The media has a tremendous influence on forming early attitudes about toxic exposure. Cwikel (2001) writes, “The media can play a pivotal role in either providing responsible information on the situation or inflating rumors that increase anxiety.” Likewise, researchers Havenaar and van den Brink (1997) state, “More often than not, media coverage tends to focus on information supporting the public fear that something terrible has happened and that the worst is yet to come.”

Journalist Robert Frank points out the responsibility of those working in the news media, “This puts a tremendous onus on news people to get the story right rather than get it quickly, a requirement for self-discipline which is present in the vast majority of cases.” However, in his personal communication to me he explains, “It’s very, very seductive to appear knowledgeable when you are not.”

Likewise, officials who are making public statements must carefully consider the needs, anxieties, and capacities of those they wish to reach, as well as the timing of their message and its crafting: the words and images that are employed, and what transmission medium will help them reach their audience with the best possible outcome. Those in authority must be especially careful about avoiding messages that highlight negative information and unnecessarily intensify fears. And when changes in attitudes are desired, those in authority also would be wise to consider that technical and statistical arguments for safety are often unappealing to persons under threat and may provide little assistance to them in their decision-making process. Instead, the communications’ persuasiveness could well be heightened when scientific data is presented in ways that are more easily understood, giving concrete examples and comparisons such as a certain load of radiation exposure would be similar to six dental X-rays or flying in an airplane for ten hours. Anecdotes and narrative presented empathetically often go much farther in conveying information in a soothing way than stark statistical data.

When fearful attitudes have been formed, they are typically most amenable to change when the source of new information is trusted and the emotions themselves are addressed so that the fear states have been calmed. Unfortunately, the supposedly fear-reducing information may prove ineffective after a disaster if it is seen as coming from those who are regarded as having failed in their responsibility to protect the populace from hazards. Once trust in official channels is broken, it is hard to restore. Also, generally speaking, communications intended to be reassuring are also apt to be ineffective when they require a good deal of thought, cognitive “work,”
to be understood, and give little attention to the emotional set that has already been developed.

Social Breakdown

The social interactions involved in the rebuilding following natural disasters often draw communities together, whereas the aftereffects of technological disasters frequently lead to heightened antagonism. Unless outsiders come in who are seen as unjustly exploitative, typically no one is blamed for the damage done by natural calamities. Technology, on the other hand, is expected to be under the control of persons having the responsibility to prevent such an accident. Technological disasters are regarded as preventable, the result of human failure, neglect, or malvolence. The people who might have kept the accident from happening, and at times, even those in charge of the clean-up afterwards, are often blamed for the suffering that is experienced, or they may be at least mistrusted, and may even be viewed as withholding important information (Green, 1998; Havenaar, 2001). This results in a loss of human trust, feelings of anger, as well as a desire to find someone to blame, and challenges to the victims’ assumptions as to how the surrounding world operates and how safe it is (Janof-Bulman, 1992).

Failure to Protect

Frequently receiving ambiguous and even contradictory information about the accident, the victims of the toxic contamination are often highly mistrustful of whatever communications they are sent by others around them or even by the authorities. One mother recalling the silence following Chernobyl states,

There were rumors but no official news. Since I worked at the institute as a scientist, I had friends who called to warn us. They told me that something had happened at the Chernobyl power plant, and that I should keep the children home. Most people knew nothing about it. There were the usual May Day parades and the weather was bright and sunny so most people were outside, working in their gardens, out in the fresh air, not knowing they were getting the highest levels of exposure. As a result, many children are now being diagnosed with thyroid cancers. If the government had warned us of the dangers and given iodine right away this could have been prevented. Now people don’t believe anything the government says about Chernobyl.

The people the government failed to protect or even warn about the possible dangers often become angry and disillusioned. Ivan Ivanovich, a Chernobyl liquidator (i.e., clean-up worker)
and organizer of an advocacy group for Chernobyl liquidators, explains how hundreds of thousands of men and women who were recruited to shut down the plant were from military or service backgrounds. As service men and women, they had medical records showing their initial good health. However, they were sent into the radiation zone without protective gear and naïve about the dangers they faced. He states,

_While the authorities still kept silent (about the explosion) the special groups had already been at work in the region of the catastrophe. They moved people out, blockaded the contaminated territory, built multi-kilometer obstructions around it, and organized a patrol service and checkpoint admission regimen. In the first days they were responsible for guarding the territory, gathering things, deactivating the land, and burying villages._

Ivanovich states that during this time there was on the part of the government “an unforgivable pause” in which information was not disseminated to either the public or the clean-up workers. However, the liquidators began to learn about the dangers they were facing through unofficial channels.

_There was a very great deal of stress when we saw the truth of what was going on. The dosimeters showed the truth. We had a wonderful doctor. When he saw the dosimeter his roof went off (this is a Russian idiom for he “lost it”). Over the 13 years since the disaster, there has become a rise in all possible diseases, including oncological and psychic, among those who lived in the contaminated area or happened to be there because of their job. In my group of liquidators, more than 192 veterans of the invisible war have already died, 167 are invalids (unable to work due to illnesses) and 162 are mentally deficient (have been so incapacitated mentally due to exposure or traumatic stress, they are unable to work and function normally). (2)_

Unfortunately, the directly-affected governments had few resources to help the disaster victims, and were apt to provide alternative explanations other than radiation exposure for the illnesses they suffered. Expressing his anger at the inadequate official assistance, Ivanovich states that in 1998, the Belarusian government rescinded small privileges given to the liquidators, such as being able to use public transportation for free. Many of his colleagues were sickly, unable to work and buy medicines. Unsure why they were ill, they blamed their illness on the radiation exposures they had experienced, and believed that the loss of this small privilege of free transportation was the ultimate insult. The Belarusian government has now remedied this situation by restoring the liquidators’ small “privileges.” Nevertheless, many people in the former Soviet Union still harbor ill feelings toward the government because of their delays in giving proper information, failure to protect their citizens, and the publics’ general cynicism over current efforts to remediate the problems.
This same cynicism toward the government is evident in other disasters as well. With the increasing importance of technology in agriculture and the growing use of genetic engineering, the possibility that toxins can contaminate food has led a good number of consumers to be suspicious of government assurances. Quite a few of them believe the officials have failed to pass laws enhancing the safety of foodstuffs and have even covered up information about the dangers in foods they are being offered.

In 1999, consumers in Belgium learned that they had been exposed to dioxin in products made from animals raised on contaminated feed. When the news broke, it became evident that the government had known about the contamination of food products for some time but had not acted. For one mother this led to a collapse in trust of public authorities. She recalls her upset and the attitudes it created:

*The problem with the dioxin scare was finding out that the authorities were aware of the problem before there was public disclosure. I think they knew for about a month without doing anything. It was not simply a day or two before the first advice was given and the decision was made to take products off the shelves. First they took the chickens, then the eggs, and then the dairy products. I was trying to diet at the time. I was on a protein diet so I was eating more eggs than normal. I was quiet disturbed to learn about the dioxin. It's a carcinogen. It creates a lot of mistrust of the authorities. Now when there is a question about the safety of beef products, I just don’t even eat it, even though all the claims by the authorities are that it is safe. There’s no reason to trust them.*

When it was reported again in 2001 that the dioxin may still be present in poultry products, and that the government had not enforced a thorough clean-up, another mother recounts her fears,

*The dioxin in the chicken products is so upsetting. I thought the problem was taken care of, but now the press reports that the levels are still high. It makes me feel like I am poisoning my children. I don’t know what or whom to believe anymore.*

A woman who lived in England during the height of the scare about BSE, or mad cow disease, that has been linked to Jacob-Creutzfeldt disease in humans, believes that a family member died as a result of contracting this illness through eating contaminated beef. Since the government was silent at the time, she no longer trusts authorities when it comes to public statements about the safety of foods despite increased official surveillance of the meat industry following the BSE outbreaks in Europe.

*My mother-in-law died of Jacob-Creutzfeldt disease. It was awful. It’s probably the worst combination of Alzheimer’s, Parkinson’s and Lou Gerig’s disease rolled into one. We don’t absolutely know if she got it from contaminated beef, but we do know that we...*
were all in London during the time when it was said to be the time of highest exposure. We were living there and she came to visit. Of course we took her out to eat often, and I remember treating her at the steak houses. We had no idea that the beef was dangerous. Now I can’t help but think that she became infected from those meals. I don’t remember what my husband and I ate but we don’t eat beef at all anymore and we certainly don’t feed it to our son. No one can convince us of its safety anymore.

This same woman goes on to explain her lack of trust in American authorities as well.

I know a lot of people who eat only American beef now. But who knows if American beef is any safer? They didn’t find BSE in German cows until they increased the level of testing. In America they say there are no cases of BSE, but I personally know of three cases of Jacob-Creutzfeldt disease. So what should we believe?

**Evacuation**

One of the countermeasures that governments must at times consider when there is toxic contamination is the evacuation of the endangered populace. This step might protect the area’s residents from the disseminated poison but it can also create a whole other set of stressors that have a seriously adverse impact on the community. A Belarusian woman recalls her mother’s sadness over losing their home in the radiated zone.

My mother is unable to adjust to the loss of her home after the disaster. She was given a very nice new apartment in Gomel, one that you would normally wait for years to get. But she hates it. Each year we are allowed to go back into the radiated zone for our holiday, Radnitza. It is the day when Belarusians normally visit the graves of their ancestors. It may sound strange, but they have a picnic at the gravesites of their loved ones. You cannot imagine how awful it has been for us each year when they allow us to go back on that day.

My mother is so happy at the time when she meets all her village neighbors again. They are reunited as a village again, briefly. They compare the ages of their children and grandchildren and look at how everyone has grown and they are happy the whole day sharing village gossip again. But when it is time to leave my mother weeps and the stress is so terrible that she is not well again for months afterwards. She suffers so much from the loss of her village and we suffer, too. These families had lived together for generations. Now they are scattered in different evacuation sites and she lives in tall building surrounded by strangers instead of her little house surrounded by people she has known all her life. It is worse for her I think than living in the radiation. She would stay in her village if she could. She leaves only because the soldiers come when the day is finished.
Indeed, in Belarus and Ukraine a surprising number of evacuees, especially elderly persons, have returned to their homes in defiance of the law. Their grief over the loss of their homes was greater than their fear of an unseen danger. Likewise, refugees from war-torn regions of the former Soviet Union have migrated to the radiation zone, preferring an unknown danger to the known dangers of war. An elderly village woman who, along with her husband and dog, had come back to live in their abandoned, boarded-up village, with only a kitchen garden to supply most of their food and absolutely no neighbors for miles around, tells her reasons for returning:

_We came back because it is our home. We prefer to live in our home than someplace else. It’s hard here. We have no electricity now and our village well is far away. We have to walk about a half hour to get water. It’s cold in the winters, of course. Our son and daughter rarely visit with the grandchildren because it’s not safe, but we see them sometimes. We are not afraid of the radiation for ourselves. We are old. We just want to live in our home._

Many ordinary persons’ decisions in risky situations are not necessarily the result of a “rational” equal weighting of the chances (as they see it) that they will (a) achieve the objectives they seek, and (b) escape the negative outcomes they want to evade. They are very apt to be “risk averse” in that their choices are more apt to be governed by the desire to avoid ill effects than by the opportunity to gain a positive goal (Tversky & Kahneman, 1981). They might then overreact to perceived dangers, even those that are not especially likely to arise. One consequence may well be an exaggerated fear of the possibility of dire health consequences. Governed by such a reluctance to risk the possibility of negative effects, government officials, and the public at large, may choose to leave a contaminated area rather than stay put, even though it is far from certain that there will be any real harm in remaining. Since there could then be unanticipated consequences to this decision, the stresses arising from the mass movement might outweigh any benefits that are attained.

**Fears about Health Consequences—**

**Stress-Related Disorders and Psychosomatic Issues**

When people are unable to grasp what scientists and politicians tell them, they often feel angry, frightened, and confused about what will best protect their health. Stress levels increase, stress-related illnesses result, and accusations fly on all sides: the population accusing those in authority of cold, uncaring responses, and the authorities blaming those who are fearful or ill, labeling them as psychosomatic, radiophobic and so on.
In 1992, an El Al passenger plane crashed in the Bijlmer district of Amsterdam, leading to rumors that lethal substances, including uranium and materials involved in germ warfare, had been strewn over the runway. Concerns were heightened when an air traffic controller testified at a public inquiry that he had been instructed shortly after the crash to keep information about the lethal substances “under his hat.” Although that information was later severely questioned, rescue workers had not been warned at the time to take extra precautions, and some people became ill. Questions arose as to the reason for these apparent sicknesses. Louis Bertholet, an advocate for those who fell ill after the Bijlmer air crash, states,

_There is frustration of those who cannot find the origin of their health problems. Those who treat them make a sharp difference from psychosocial and health problems. The general practitioners mostly say, “What you feel is between your ears.” As a result the victims get no medications and when they can’t work, they get discharged from work. These people get socially alienated and lose their dignity. When research was done, the studies were merely paper research. Patients phoned in and filled out symptom checklists. As a result, the only conclusions were there was no significant deviation (as a result of the accident)._

_Only that autoimmune disease was found more frequently and posttraumatic stress disorder (PTSD), and this was blamed on the victims psychosomatic state. We found that this nice literature study infuriated quite a lot of victims. No one came forward to comment. The coldness of authorities responsible for looking into these cases is stunning. For example we find the same lax attitude with BSE causing Jacob-Creutzfeldt disease in humans. We know three people in the Netherlands that succumbed to this disease. Yet official figures show no cases. We hear over and over again of patients being told their problems are all “between their ears.”_

Uncertainty about the causative agents, futures risks, and amount of damage already done in technological disasters often makes it difficult to ascertain how much of the health effects is due to mental distress and how much arises from the actual toxic contamination. The difficulty of trying to find out what is psychosomatic—i.e., caused by stress—and what has been produced by toxic exposure is a very delicate issue and at times impossible to resolve satisfactorily. Many of those exposed to the Chernobyl disaster, for instance, blame all of the illnesses on radiation, even though quite a few scientists consistently claim that an increase in thyroid cancer among exposed children is the only scientifically well-substantiated effect. Clifton’s chapter summarizes some of the relevant research findings.
It is not uncommon to hear people tell stories about relatives who are ill or who have died of cancer after the Chernobyl catastrophe. They are convinced that their family members became ill or died early because of radiation, and no one is likely to convince them otherwise. They raise serious questions about the scientists’ statements and often brush away, in a sweep of opinion, the numerous scientific efforts to quantify the adverse health effects of the Chernobyl accident. One well-educated Belarusian woman recalls her sister and family member’s illnesses.

*I know all about what the Western scientists say about Chernobyl. I know they say that it is only the children who are getting ill, and it is only thyroid cancer that is caused by the radiation, that the rest is not from Chernobyl. But I know what is happening in my hometown. I grew up in the area where the radiation is now the worst. All my family still lives there. My adult sister has thyroid problems and so does my cousin. She is so ill she cannot raise her own children. And her daughters are ill. I have to give her all the money I can to help her buy medicines. No one can ever convince me this is not from Chernobyl. I know what I see with my own eyes.*

On the other hand, the secondary gains obtained when health or social benefits are tied to being diagnosed as a victim of radiation exposure only adds to the difficulties in identifying just what are the specific consequences of the contamination. After the Chernobyl disaster, because those people having official certificates stipulating that their illnesses were Chernobyl-related could receive health and monetary benefits, other persons sought to link their own illnesses to Chernobyl. As another benefit, every year, hundreds of children are given the opportunity to take health vacations at spas set up in the countryside for recuperation from radiation exposure, and some youngsters are even hosted for summer respite trips in Western countries. Some of the participants in these trips undoubtedly had not suffered much radiation exposure, but instead, had profited from having a parent who was a party boss, or otherwise someone of influence, so that they were chosen for the privilege of an out-of-country journey.

When people do become seriously ill, it is even hard for those working with them to know the sources of their problems. Chernobyl researcher and psychologist Valentina began collecting data on the military and policemen she worked with who had served as Chernobyl liquidators. She found various serious health problems, all of which could be either psychosomatic, i.e., stress induced, or radiation related. For instance, seventy-five percent of her all-male sample suffered impotence at various time periods over a thirteen-year time span following the disaster (Valentina, 1999). She was unable to determine if the impotence was physiological or psychological in origin, although it was responsive in many cases to urological or to psychological...
interventions, depending on the person involved. On the psychological end of things, Valentina found that many of the liquidators feared fathering children with genetic defects because of their exposure to radiation and that frequently wives and potential partners shunned them for the same reasons.

Even now, many scientists claim that there are very few, if any, long-term health effects of the Chernobyl disaster, and impotence is not recognized as a scientifically-verified effect of this level of radiation exposure. Likewise, scientists insist that fears over genetic mutations are baseless. Yet many medical workers in Belarus report seeing what they believe is a significant increase in birth defects. This rise obviously can be explained away by arguing there has been an increased attention to such unfortunate births. However, a new study comparing children conceived by liquidators before and after the Chernobyl disaster finds “an unexpectedly high (sevenfold) increase in the number of new fragments of DNA in children conceived after their parent’s exposure compared with the level seen in controls” (Weinberg, et al., 2001). The authors state that their results indicate that low doses of radiation can induce a high rate of mutations. However these findings are interpreted, it is clear that residents of the contaminated areas, sick patients, their health care providers, and even researchers, disagree about the causes of the many illnesses in the high radiation areas, what the effects of radiation might be, and what should be done about the threat of radiation— and these disagreements in turn create more stress for all.

**Posttraumatic Stress Responses**

The psychological consequences of technological disasters are often chronic as well as acute, with long-term uncertainty and anxiety typically present in both cases. As the stress continues, the threatening information about contamination can reach a saturation point where the threat is perceived as “overwhelming, horrifying, life threatening and, inescapable,” and thereby becomes a traumatic stressor. When this occurs, posttraumatic stress disorder (PTSD) may ensue (APA, 1994). However, because the traumatic stressor is often information only versus an overwhelming sensory experience as when a tornado or hurricane hits, the ensuing posttraumatic stress symptom pattern may differ from that elicited by an “actual” or more sensory danger, as will be discussed below.
Hyperarousal

News of a widespread contamination from a technological disaster is obviously frequently threatening, and can at times produce not only fear but also hyperarousal. The media can play an important role in generating these adverse emotional reactions. Seeking the largest possible audience, television and press coverage often emphasizes the most dramatic and most vivid features of the event, which frequently means highlighting the most horrifying aspects of the disaster. The public’s anxiety level may then be intensified to an undesirable degree. As one result, for example, the affected people’s ability to reduce their anxiety through psychological avoidance mechanisms and denial could be diminished and intrusive images of the possible horrific consequences of toxic exposure might create increased agitation.

An emergency worker who witnessed the Biljmer air crash and worked amidst the wreckage without knowing she was potentially being exposed to toxins, states that she cannot escape the constant barrage of frightening news about the possibility of harm even nine years after the event.

Every time there is news, I am upset. This is constant. It keeps bugging your mind. It brings it all up, the anxiety and the pain and frustration of not getting answers. We just want to know why we are all sick.

Despite actually witnessing the crash and working amidst the carnage, this woman feels that her posttraumatic stress is less from the traumatic accident as from the ongoing horror over time of watching herself and people around her become ill with no help or explanations readily available. She believes the contamination might be making her and the people around her ill, and found the official explanations of the possible after-effects unsatisfactory. In her assessment, the actual disaster is not as awful as living with the fear of toxic contamination.

I saw the plane crash down. I was with the fire brigade. I worked at the site for a week. It was the first time for that kind of work. It was not fun, but it wasn’t the hardest part. It was something awful, but you can live with it. It’s over, you’ve pictured it. The hardest part was two years later when colleagues became sick. One got cancer, one got skin problems, all kinds of diseases. There are people living in the area with the same complaints. They all complain of the same things. Most of the complaints are tiredness. There was a school close by. After the crash, children played on the playground with the same dust and some are sick. I wasn’t feeling well. Later I was diagnosed with fibromyalgia. The only thing in common was we were at the same place at same time. I have pain in my muscles and if I do too much, I have pain, and I have trouble getting to sleep at night.
Avoidance

Threatened persons cope in a variety of ways. If not too overwhelmed, they will often seek information they can employ to increase their resources and options and thus deal better with the situation confronting them. For highly traumatized individuals, however, this search for additional information can be troubling, telling them more than they want to know, more than they can effectively make use of at that time, and thereby, fueling a state of hyperarousal.

Not surprisingly, then, very frightened persons often attempt to avoid additional information, and constrict many of their activities that might trigger even stronger feelings of threat. They attempt to lessen their arousal states by avoidance.

But this avoidance can also conflict with actions that might be helpful in responding to the disaster. For instance, continual avoidance may help foster a state of “learned helplessness” (Seligman, 1975) in which they are unable to do virtually anything to deal with the problem before them and cannot undertake whatever protective actions are possible on that occasion. This was observed in Chernobyl victims who could not cope with the high levels of radiation found in their foods after the disaster. One woman recalls:

*There were dosimeters placed in every town market so if you wanted to you could measure the levels of radiation in the food you were buying, to be sure it was safe. But what happened was that so many foods registered as unsafe that people were either afraid to feed their children anything, and they were becoming malnourished or people just stopped measuring their foods. It’s hard to throw away berries from your garden that every year you have made into jam for your family. People found it was just better not to know, since they really didn’t have any good choices anyway. They were too poor to find other foods than what was offered in their areas. Slowly the devices started disappearing and I think most of them were locked away in government offices.*

Svetlana Alexievich, the author of *Chernobyl Prayer* (2001), a book chronicling her travels in the Chernobyl zones, recalls her anger at one mother who was overwhelmed by stress:

*I call it the cult of helplessness. It is the sickness of our country. I visited this mother out in the villages. Her daughter was very, very ill from radiation. She was possibly going to die. This mother had been given very expensive Western medicines to treat her daughter, but she was not giving them to her. When I asked her why not, she said she could not read the instructions as they were foreign and the labels were not in Russian so she didn’t know how to treat her with the medicines. She cried and said, “My daughter is going to die, it’s my bad fate.” It made me furious. Why couldn’t she put herself on a train and go into the city to ask the doctors how to use the medicines she had been given. She was so helpless, she was going to let her daughter die!*
Another mother, who was asked about her level of concern about the food in Belarus, replied,

You know we don’t have the luxury of going out of the country to buy foods. We have to buy what’s here. I always hope it’s safe for my son. But I couldn’t live if I thought about it all the time. I just have to put it out of my mind.

In spring of 2000, when the Israeli embassy in Belarus detected high ambient radiation levels that could have indicated renewed danger from the exploded Chernobyl reactor, the embassy was evacuated. When the news reached one resident of Minsk and she was offered protective measures, she refused to be alarmed, explaining how she had become numb to fears about another incident:

Thank you for the iodine tablets. I’ll take them for my children, but honestly I am not very worried. You know this happens every spring around the anniversary of Chernobyl. The rumors start circulating that Chernobyl has exploded again. I used to get worried about it, but now I don’t even listen. I don’t know why the embassy evacuated. I hope it’s nothing, but I don’t think I will keep my children inside the house. I can’t get excited every time the rumors start or I’ll go crazy.

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**Flashbacks & Hyperarousal**

Technological traumas are generally not experienced in the same manner as are other types of disasters. The relatively short-lived sensory overload and intense feelings of helplessness and fear arising during natural calamities such as an earthquake, hurricane, or tornado may be quite different from the emotional reactions produced by technological disasters.

Since the traumatic stressors can be so different, one highly sensory and the other highly cognitive, their “flashbacks” —vivid images of the occurrence that come to mind in an involuntary and intrusive manner (Schacter, 1996)— can differ as well. For instance, flashbacks of a flash flood recreate the hyperaroused state that was present at the time of the original trauma. If the original trauma was rich in sensory details, the flashback is likely to be as well. By contrast, flashbacks of a toxic trauma are generally more cognitively constructed and so, are typically much less of a close representation of the event. Over time they link once benign scenes with new horrific meanings that were not originally present. Showing just this, a Chernobyl victim states that she always has flashbacks of the disaster on sunny days when there is rain, because the strange rain following the seeding of the radioactive cloud in Belarus came on a sunny day.
Although she had been completely unaware of any danger on that day, she now has flashback recollections of the occurrence that evoke a high level of traumatic arousal. She now has to utilize strategies of avoidance to keep the intrusive thoughts from overwhelming her with anxiety.

Cognitive information received at a later point in time can change dramatically the construction of a once-experienced benign event into one that is presently construed as traumatic and capable of engendering PTSD. This change in the meaning of an event not originally experienced as traumatic has been discussed in relation to other traumas (Speckhard, 1996). Whether the event’s dangerous meaning is established right away or only later, and whether the flashback intrusions coming to mind are accurate representations of the incident or not, post-traumatic stress disorder (PTSD) can ensue if the trauma is overwhelming and goes unresolved so that hyperarousal states are readily evoked.

For us here, though, the important point is that new information coming along later can change the meaning of past events, even in memory, so that the earlier occurrence is now experienced in the present as traumatic. There could then be a delayed onset of PTSD with intense anxiety-provoking flashbacks. This process is illustrated by the horror of a Chernobyl liquidator who recalls being in charge of a large garrison of men. He wept, recounting how he sent young recruits to work on the construction of the concrete sarcophagus enclosing the highly radioactive ruins of the exploded reactor:

“We didn’t know then how dangerous it was. They had no equipment, nothing to protect them from radiation, not even masks or special clothing. We didn’t know at the time that many of them would become ill and some die from it. They were all military and policemen who were sent to help. There was not a single person who refused. It was our duty to defend the people. But now, every day I see the faces of those men I sent to their uncertain futures, and I remember those who died already and I feel sick from it.”

Flashbacks that occur in such cases differ from the more usual traumatic intrusions because they involve images of a once benign scene to which extremely negative emotions have subsequently become associated. These flashbacks have a relatively complex cognitive quality and the hyperarousal generated may differ substantially from that arising more directly from dangerous occurrences.

This qualitative difference in flashbacks was noticed in research with Chernobyl clean-up workers (i.e., liquidators) (Tarabrina et al, 1993). Employing a well-recognized procedure in which the participants are asked to respond to described traumatic incidents, these researchers elicited a PTSD-like reaction, as defined by standard self-reported trauma measures, in a sample of liquidators. However, when the investigators tested to see if hyperarousal was present by as-
sensing for it physiologically (cf. Pitman, et al., 1987), they found no such indication of a hyperaroused state. The researchers’ conclusion was that liquidators did not truly have PTSD since they did not evidence bodily hyperarousal in response to scripts that should induce flashbacks. However, it could also be that for survivors of a toxic trauma, verbally-induced recollections of the hazardous event are not sufficient for creating posttraumatic hyperarousal. These memories may not involve enough of the additional meanings the victims have attached to the incident, especially meanings having to do with possible future happenings. The traumatic thoughts in this sense move ahead in time. The present author has referred to them as a “flash-forward” (Speckhard, 2001, 2002).

**Flash-Forwards as Posttraumatic Responses to Toxic Traumas**

Victims of technological disasters often experience horror in their imagining of what will happen in the future. As one example, the Chernobyl victim who had been exposed to high radiation as a child may then see himself as a cancer victim in years to come. He pictures himself bearing the “Chernobyl necklace,” the ring-like scar around his neck that signifies the removal of a malignant thyroid gland. And similarly, the pregnant woman exposed to a toxic contaminant may continually flash forward to the birth of a “monster,” fearing to continue her pregnancy but loath to abort it.

Survivors of toxic calamities often develop a unique trauma-induced time distortion that is perhaps well termed a “flash-forward.” In these cases there is the constant intrusion and re-experience of a horrifying, inescapable, and life threatening event that the survivor expects to happen in the future as result of having been exposed to a toxin in the past. These flashforwards are repetitive, intrusive, and create acute emotional distress and bodily agitation similar to the hyperaroused state typically observed with flashbacks.

A Chernobyl mother recounts:

> *My daughter was frequently sick after Chernobyl. Every time she became ill I would panic and imagine her with cancer. I could hardly bear it. Then 15 years after the catastrophe, they found a tumor. She had to have thyroid surgery. She has the “Chernobyl necklace” now. She is so beautiful. But when I look at her I see that white scar running across her neck and I feel a chill inside. I’m so afraid of what can happen. It comes to my mind over and over again and there is nothing I can do but pray. Chernobyl plays a huge role in our lives. We can never escape it.*
**Feelings of Future Dread and of a Foreshortened Future**

As one example of how the mind can distort the sense of time, traumatic events often remain in the psychological present much longer than do non-frightening, normal events, in part because of the flashbacks and other unpleasant recollections that arise in response to relevant cues (Kronik, et al, 2000). On the other side of this coin, we can say the adverse posttraumatic consequences of a calamity are successfully resolved when one can discuss the occurrence with the victim, as though this incident now resides in the past instead of continually looming in the present and future. And moreover, it can be discussed without the victim becoming emotionally overwhelmed and unable to continue talking about it. In the best resolutions, the event is incorporated into the person’s life history in a manner that endows the event with some positive meanings, such as when the community’s helpful and supportive response to the disaster is remembered as a positive attribute of a traumatic event.

Unfortunately, stories in the mass media about the toxic contamination, such as on anniversaries of the catastrophe or when more information is uncovered, can reawaken the memories of the horrific occurrence and evoke a state of hyperarousal and an inability to put the disaster in the past. Frequent retelling of accident, in the media or by members of the public, can make it difficult for the victims to avoid viewing themselves as damaged and their futures as spoiled. For instance, as Johan Havenaar (2001) writes, with each anniversary of the Chernobyl disaster, victims find themselves confronted with even more stories of disease, invalids, birth defects, and long-term environmental poisoning, some of which are not even possibly likely. It is hard under the circumstances to not have anxieties continually stirred up.

**Social Alienation Following Toxic Contamination**

Lastly, contamination stressors can produce a special sense of alienation lasting a lifetime after the exposure. The people exposed to the toxins might come to view themselves as freaks different from those who had not been poisoned, and/or the contamination might render their homes or workplaces no longer useful, shattering their communities and expectations of themselves and others. The uncertainty regarding the effects of the toxic exposure on their genetic structures and bodily functions can be of sufficient concern to cause women to abort pregnancies, prompt couples to worry about future reproduction, and darken people’s future expectations.

Victims of these toxic disasters may live with ailments that are difficult to diagnose and treat, and often come to bear the stigma of being genetically changed. An advocate for victims
of the Bijlmer air crash who believe they were exposed to germs genetically altered for biological warfare explains:

One mother was diagnosed with Mycoplasma Fermentans Incognitus, a slow-growing, manmade, manipulated microorganism that can resist extreme heat and cold and can be vector of many diseases . . . Quite a few had a chronic Mycoplasma infection and are being treated for it. . . . One woman said: “My periods have returned and I’m starting to come back to regular cycles and I feel much better, not cured, but I hope I can function close to normal again.” One was bedridden and in a wheelchair, after diagnosis that she had a chronic infection with Mycoplasma Fermentans.

Issues of Grief and Loss Following Toxic Contamination

When dealing with those afflicted by toxic disasters, it is crucial to address the victims’ terrible feeling that they have been damaged irreparably by contamination and the loss of home and community. More than losing their ability to work, their future prospects seem bleak to them. An advocate working with a victim of the Bijlmer air crash describes one young man:

He has suicidal thoughts. He says, “The only thing I can do is listen. He asks me how can you help us while nobody of our government wants to believe you! Let me die, nothing can help me anymore. Let nature run its course.” His future as a songwriter and musician is without reach. He was quite a way up the ladder! All five of the original animals in their home died mysterious deaths. Even the veterinarian had questions he could not answer.

The confusion, grief, and reluctance to leave their contaminated homes and possessions continue to be terrible problems for those victimized by the Chernobyl catastrophe. The residents of the radiated areas could not understand why they were forbidden to take family treasures with them, or why the family cat, dog, or livestock were to be shot and buried. Some refused to leave their homes, and hid from the militias whose job it was to evacuate entire communities and remove others who had returned illegally to live in contaminated areas. Many evacuees were stunned to learn that after they left, their entire villages were bulldozed and buried beneath the soil.

In an art exhibit following Chernobyl, one child portrayed her family’s grief at leaving their home. She captures their sense of total loss by depicting her father kneeling beside their boarded-up home, scooping up a small satchel of soil to take with him, soil that is contaminated and unsafe to carry, but nevertheless is precious to him.
Positive Coping versus Hypervigilance and Depression

Individuals who become sick and/or have health worries after toxic disasters are especially at risk for serious emotional problems. In addition to feeling frustrated at not being able to find answers to their questions, their need for information they believe they could use to protect themselves, and the frequent arousal of their emotions by conflicting reports on the disaster can lead to one of two fairly extreme reactions: either hypervigilance, in which they continue to attend to messages about the calamity, or on the other hand, depression that prompts them to avoid everything to do with the accident and give in to despair. Community advocate Louis Bertholet speaks about a family living near the Bijlmer crash site as an example of the latter reaction.

There is a family of four who live on the fourth floor of one of the high-rise apartments so typical for this multicultural quarter of town. On the day of the crash this part of the apartment was constantly in the smoke. You just could not escape it. Smoke entered their apartments; they walked in full smoke when they left their houses. The house was filled with friends who later on have become ill also. The family has two children in their early twenties, late teens and lots of animals: four cats, a parrot, and two dogs. That night the husband went out; saw all the misery and helped where possible. He put his hand in a deep wound of someone’s head to stop the bleeding. He lost his memory totally and saw by television that there was in 1992 a plane crash.

In time the health problems for the family started with vague complaints, difficult to diagnose. It became increasingly more difficult to go to work every day. Then the whole machinery of the “welfare state” starts to grind. As long as the periods of illness are short, nothing is wrong. But when with breathing and skin problems and tiredness alone and no cause can be found, people have to fight for their livelihood. The terrible coldness of the bureaucracy is stunning. All four of the family are out of a job; they live on the poverty line. The mother who has been mentally very strong, helps where possible, is the listening ear to many apartment dwellers around her, can not see the suffering of her children any more. When I came to her to let off steam and of course to be a listening ear, she said to me: “Look, Louis, I bought a large plant-forcing bed (45cm x 120cm) for on the balcony. When I die, put me in it and bury me in it, it’s my size and it is cheap and good for a dehumanized being. This must be my coffin.” It breaks your heart, I’ll tell you.
A similar phenomenon was noted after Chernobyl. The government, along with many Western donors, purchased radiation-measuring devices for people to employ in testing the radioactivity of foods they bought, raised, or collected from the forests. Many used the instruments at first. But they later gave up in apathy and stopped trying to find out what was safe to eat and what was not when it became apparent that they could not reject available foodstuffs as too dangerous, especially the berries, mushrooms, and other foods that were so much a part of the culture, and still adequately feed their families. It was too depressing to comply with measures that caused more stress than the fear of radiation. Breaking rituals handed down generation after generation, such as gathering spring mushrooms, could be as depressing as the possibility of ingesting radiation.

One woman who tried to comply with the many health precautions broadcast over the radio after the disaster recalls:

*I am a person who can follow rules, especially if I think they will protect me. At first I tried to do everything they said. We took our shoes off before coming in the door and washed all the dust from them so that we wouldn’t bring the contamination into our homes. We kept the windows shut all day, even though it was hot and stuffy inside. But as the rules increased, I began to see that it was impossible to do everything they said. How could I keep the cat from coming in and going out? How could I live in a room where I never opened the windows? It was too hard and I have up and stopped listening. Maybe I endangered my health, because now I have thyroid problems and I am part of a research study where they keep observing it to see if it will become cancer. But I could not do everything they told us to do. Now I don’t even react when I hear the news every spring about Chernobyl exploding again. There is nothing I can do.*

**Vulnerable Populations**

*Mothers of Small Children*

In the majority of cultures, women and mothers traditionally carry the burden of being the chief health-protectors for the family. They frequently are in charge of food selection, hygiene in the home, and the oversight of children and medical care. If a toxic exposure threatens the home, mothers can become overwhelmed by the demands involved in protecting their families. After the Three Mile Island nuclear accident, mothers were found to have a fairly high incidence of anxiety and depression. Researchers also reported a sharp increase in distress following the restart of the reactor (Bromet et al, 1989).
Fearful for their children, mothers in these situations can develop hypervigilance and become overly reactive to common occurrences that might portend danger. And so, health workers and teachers in the Chernobyl-exposed regions frequently note that mothers keep their children home from school for minor ailments and become extremely worried about common illnesses, particularly anything possibly related to the thyroid. Research with this population also finds mothers are more likely to report health problems in their children than do the children themselves, highlighting the mothers’ hyperawareness to problems the children consider inconsequential (Bromet, 1995; Bromet, et al 1998; Evseenko, et al, 1999).

**Gender differences**

Males and females, on the whole, also typically respond differently to stress. Whereas women are generally more prone to anxiety and depression, men are more likely to act out their stress or turn to substance abuse. Perry (et al, 1996) found that young girls involved in a disaster coped more frequently by dissociation than did boys, and that in abused populations, boys were highly likely to be diagnosed with conduct disorder. Likewise, Gottman (1993) reported that in marital situations, men became emotionally aroused more quickly than women and spent a longer time in their arousal states, i.e., were less able to reduce this arousal quickly. If these differences can be generalized to situations of disaster, which is likely, they suggest that men and women may respond differently to crises, and perhaps even to communications designed to bring relief.

**Pregnant Women and Conceiving Couples**

Exposure to toxins is particularly worrisome to pregnant women and those couples contemplating future childbearing. Many women following Chernobyl worried about pregnancies they were carrying and about their own reproductive health and that of their partners. A good number of men who had worked as liquidators containing the radioactive fallout found that women who feared conceiving malformed children shunned them as sexual partners. Many of those who received large doses of radiation worry about childbearing. A Chernobyl liquidator whose family lived in the Gomel area near the highest levels of exposure remarks:

*My daughter will never have children. We lived in the area of high fallout and my daughter was exposed to radiation after the explosion. She has seen too many babies*
Many women aborted pregnancies after Chernobyl out of fearfulness, even though they had desired children. A twenty-two percent rise in induced abortions was observed as far away as in Denmark in the months following the Chernobyl catastrophe. Based on Danish national register data, Knudsen (1991) stated that fear of radiation from Chernobyl probably caused more fetal deaths than the radioactivity itself.

One woman recalls her horror being pregnant during the Chernobyl disaster:

*I was pregnant when Chernobyl exploded. We lived in Kiev, which was very close by and down river from the plant. We had no idea it had happened until days later. It was sunny weather so we were outside, exposed. But later we learned. At that time, everyone was panicking, sending their children away. You couldn’t even get close to a train at the station. It was the most horrible moment for me. I didn’t know what to do. Everyone said to have an abortion. Most pregnant women aborted but I decided against. Later children who were exposed started having problems. Some got thyroid cancer. It was awful. Children were born with defects. I was nearly out of my mind the entire pregnancy. I look at my son and think I can’t believe this happened to us. I hope he never becomes ill from it. He is my only son. I will never have another pregnancy. I’m too afraid to even think about it.*

For years government officials in the former Soviet Union were not allowed to label illnesses as Chernobyl-related. It is therefore unclear whether or not birth defects are on the rise in the region. However, the World Health Organization recently began to state its concern that Chernobyl may be responsible for increased birth defects. One Belarusian woman recounts her fears about having a child in the future,

*I don’t know if I can have a normal, healthy baby, but I avoid finding out because I am afraid. I think the thing that made it too real for me was when my cat became pregnant after Chernobyl. She had normal litters before, but these kittens were all deformed. I took her to the vet and asked what was wrong with her. They said, “Chernobyl of course.” I was so stunned. It felt like it could have been me. If I ever do decide to have a baby, I will leave my country for at least a year before I become pregnant. My cat also had the final Chernobyl end. She died from cancer.*

Another Belarusian woman who lived in the area of high fall-out from Chernobyl told about her obsession to date only foreigners in order to bear a healthy child,
“I must marry a foreign man to get good genes for my child. I will not have a baby with any man from these areas. And I must live outside the country for at least two years with clean foods and clean environment before I become pregnant. Only in that way I can have a healthy baby.”

In this case, she was ignoring her own potential to pass on damaged chromosomes and rationalizing that foreign genes would outweigh the potential damage to her own.

**Treatment Issues**

Those who work with victims of toxic disasters move in partially uncharted territory. What is known, however, is that these victims are often distrustful, frightened, tired, and disheartened. They want information that they can trust, and they want to protect themselves, but in ways that are not too overwhelming. Depending upon how traumatic the experience was, victims may have posttraumatic sequelae, including time distortions in which the past dominates the present as well as reaches into the future and thereby poisons for them prospects of a bright time to come. Psychological interventions and other protective strategies that dispel fears, reduce anxieties, and lessen the sense of loss can “detoxify” the trauma of a toxic disaster. With their self-concepts apt to have been damaged along with their homes and communities, the victims may well require help rebuilding a positive sense of themselves and those around them. Their despairing cynicism and shattered assumptions of a safe world and protective authorities can be replaced by a belief that they and others can deal with the threats facing them. And a heightened sensitivity to the needs of others similarly hurt resulting in increased social bonding and even community activism can also be promoted.

More work needs to be done in the scientific community if we are adequately to understand the adverse effects of stress as it interacts with toxic exposure and to develop trustworthy disease models. Likewise, those in authority and in the mass media must learn to present negative, and possibly frightening, information in ways that do not worsen the situation for those involved. These are formidable tasks, especially considering the paucity of reliable but relevant data. But the challenge of dealing with the threat of technological calamities and highly toxic accidents will be with us, and even grow, in years to come.
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Endnotes

1. Anne Speckhard, Ph.D. is adjunct associate professor of psychiatry at Georgetown University Medical School and professor of psychology at Vesalius College, Free University of Brussels. She also works as a trauma psychologist and researcher on this topic and others in the U.S., former Soviet Union, and in Europe. She lived near Chernobyl with her husband the U.S. Ambassador to Belarus, from 1997 to 2000 and has consulted with researchers and clinicians addressing Chernobyl related trauma issues. She can be reached by e-mail at Aspeckhard@brutele.be or by post at 3 Ave des Fleurs, 1150 Brussels, Belgium (from the U.S. at PSC 81, Box 135, APO AE 09724).

2. Because the contamination was impossible to see, Ivanovich refers to the clean-up effort carried out by conscripted militia units as an “invisible war.”

3. Speckhard studied women whose abortion experiences became traumatogenic when changes in life circumstances, values, or information, changed the perceived meaning of a once benign abortion experience to an event that was perceived as horrifying, overwhelming, involving death, and inescapably traumatic. For example some women who viewed an ultrasound or pictures of a fetus the age of their aborted fetus subsequently changed their view of the procedure that was previously undergone from that of a routine D & C to that of a traumatic death event for which they felt grief or guilt. Likewise a woman who subsequent to an abortion, miscarries a pregnancy, bears a disabled child, or learns she is unable to ever bear children may upon receiving
Chapter Twelve

DEVELOPMENT OF ADAPTATION PATTERNS AMONG POPULATIONS AFFECTED BY THE CHERNOBYL DISASTER

Yuri Shvalb

Almost two decades have elapsed since the accident at the Chernobyl nuclear power plant. Naturally, the perceptions and feelings related to the disaster have become less dramatic over the course of time. In this chapter we deal with just one aspect of the issue: whether we can come to believe that we have learned how to “live with radiation.” In the research project summarized below, our task was to identify the behavioral patterns in the population that might help in the adjustment to disasters of this nature.

Other chapters in this book, and a great many other publications as well, describe both the accident itself and the dynamics of its consequences and impacts. This article will therefore dwell only on those aspects that are directly related to the formation of behavioral patterns that people have developed to cope with the aftermath of the disaster.

Characteristic Features of the Chernobyl Accident

The first characteristic feature to be taken into consideration is the fact that while the Chernobyl accident has an identified starting point, there is no ending point, at least within the time-frame of human life expectancy.
The Chernobyl accident also differs from the usual run of natural calamities or environmental or technological disasters. At their most extreme, natural calamities are occurrences leading to the destruction of environmental conditions necessary for human life. But regardless of their destructive force and horrendous effects, people always have a chance to get back to their former mode of life when the events come to an end. Moreover, great numbers of people usually have lived for a very long time in the areas subject to frequent natural disasters, and over the years, they and their predecessors have developed traditional ways of overcoming the hardships brought on by the unfortunate events and their unavoidable losses.

Environmental disasters usually do not have a precise starting point. Their adverse effects often develop gradually and can accumulate for years or even decades before the consequences become so severe that they are readily detected. We can identify several behavioral patterns developed as a response to these environmental disasters. In one pattern, people have enough time to adjust to the injurious changes and often regard those changes as “natural.” They can modify their work, consumption patterns, and social interactions without any serious social or psychological discomfort. The former conditions of life remain in the collective memory largely as myths and legends. Alternatively, people simply abandon the areas which, in their opinion, are no longer fit for habitation, although in the modern world this becomes less and less possible. In a third pattern, concepts related to the environmental control of disasters become more common and widespread.

Technological accidents are characteristically sudden, destructive events that affect people who happen to be inside the afflicted areas. For the majority of these persons, the technological dangers they confront constitute a certain “risk zone,” that is, are regarded as having some degree of probability. The attitudes that then develop and the behaviors that are carried out in response to these threats are greatly influenced by the level of acceptability of certain perceived or actual “risk” factors. Improvement in the safety of the technologies that are employed, staff training, and public education can reduce the estimate of risk but do not assure total safety.

The Chernobyl catastrophe combines some important features of natural and environmental disasters and technological accidents, but at the same time had its own peculiarities. We therefore cannot fully understand the behavioral patterns developed at Chernobyl simply by extrapolating from the development of behaviors at other catastrophe sites facing different circumstances.

The second characteristic feature of the Chernobyl accident is the fact that radiation, the most dangerous threat arising from the disaster, is not visible. It does not have highly salient characteristics which can be readily identified by human organs of perception (eyes, ears, nose,
It is obviously extremely difficult to adjust one’s behavior to a non-perceptible factor. People living in the contaminated areas usually know of the existence of special devices (such as Geiger counters) by which the radiation rate can be easily measured. However, they do not use these instruments in their everyday life even though many of them have become supersensitive to what they regard as “perceived” radiation effects. Some persons claim they “see” radiation and are able to define its intensity by an object’s “luminescence.” Others maintain they can identify radioactivity by its smell or by the itching on their skin or tickling in their throat. Although radiation specialists deny the possibility that radiation can actually be detected in these ways, people are often guided by their own feelings and beliefs and form their behavior accordingly.

The third characteristic of the Chernobyl accident, as other chapters in this book make clear, is the multi-factorial nature of the radiation. Diverse chemical elements—iodine, cesium, strontium—were released from the Chernobyl reactor. Each has a different intensity of radiation, a different half-life, and forms different compounds with other substances. Each element also affects the body differently and is accumulated differently in various parts of the human body—in the thyroid gland, in the lungs, in blood-forming organs, and so on. People also vary in their body’s resistance to the harmful effects of the radiation. All this means that ordinary people, as well as quite a few specialists, often fail to take into account the many complexities involved in radiation effects, and this inadequate comprehension can heighten the difficulty of managing or controlling the adverse effects of radiation on the health and life of exposed individuals.

The fourth characteristic feature worth mentioning is the difficulty of differentiating between the accident’s direct and indirect negative effects. Radioactive contamination of soil can be regarded as a direct consequence of the accident, but what about contaminated food products? And how shall we measure the impact of diseases and conditions that may be psychosomatic in origin? There is no end to the list of questions that can be asked as to whether the after-effects are direct or indirect consequences of the catastrophe.

A number of subjective characteristics can be added to these objective aspects of the Chernobyl accident. Among these, the following are the most important:

- No relevant past social and individual experience in similar circumstances;
- Impossibility of distinguishing between reliable and false/fictitious information;
- The absence of visible changes in the environment in the years following the accident;
- Absence of managerial decisions at all the levels of administration, from national to
local, and inadequate understanding of decisions that were made.

The joint impact of these objective and subjective factors has resulted in a situation unique in the modern world. Faced with the extremely complicated reality of the accident, insufficient reliable information, and inadequate guidelines for their perceptions of what happened, the affected people could not come up with suitable cognitions regarding the accident’s consequences on which they could rely, and which would help them develop truly adaptive behavioral patterns.

Adaptive Myths and Magical Thinking

When collections of people are confronted with threatening ambiguous circumstances and have difficulty engaging in rational problem-solving, they frequently develop alternative cultural forms and relatively new interpretations of their experiences. First and foremost, they often develop psychological mechanisms based on myths and magical thinking.

Myths are among the oldest and most durable ways by which a culture organizes and interprets the group experience and regulates individual behavior. A complete myth contains the description of what is the exemplary action given the circumstances of the myth and explains the reasons for, and meaning of, a given behavior. The explanation, or justification, provided always goes well beyond actual individual experience. In classical myths this extension has always been achieved through imparting divine status to the exemplary action. The structure of a myth enables the individual to discard issues of motivation: “Why should this be done?,” or “Why should that be done this way?” The action is simply accepted as proper or warranted in the situation.

Magic consciousness and magic action are rather close to myth in their structure, although they each have their own peculiarities. In ordinary thinking, magical action is usually associated with, or confused, with sorcery. Psychologically, on the other hand, an action can be considered “magical” when no rational linkage can be established between the action taken and the apparently resulting outcome. Unlike the myth, which provides the individual with a sense of knowing what is going on, magic furnishes only an inexplicable link between what is done and the expected results.

My conception of the formation and functions of the adaptive myths (sets of beliefs) and magical thinking developed in response to the Chernobyl calamity can be summarized in the following manner:

In post-Chernobyl reality, for many of the persons in the area, it is impossible to create a sensible
and rational picture of actual developments. Individual experience does not provide any clear
guide for action. Myths and magic therefore become common forms of consciousness and are
employed in the regulation of life activities by the overwhelming majority of the population.

The basic views (i.e., mythologies) defining public attitudes toward the accident came into be-
ing within a few months of the catastrophe. Some of these initial myths eventually disappeared
from people’s minds, while others have taken root and established themselves as elaborate sets
of beliefs. Those that have survived can be divided into two main types based on their attitude
towards the accident and what pattern of behavior is favored in the face of radiation.

The first set of beliefs defines the general emotional attitude toward the accident as a
whole, and the danger of radioactive contamination in particular. Put simply, this general clus-
ter of views varies between a strong pessimism at one extreme and a clear and definite optim-
ism at the opposing pole. The optimistic pole is represented by the myth of usefulness. In its
most extreme form, this belief pattern holds that: “Small doses of radiation are useful for people
of middle and old age.” This myth has been supported by various supposedly “indubitable”
facts. For example, it has been argued that a great number of people remarkable for their lon-
gevity in the former USSR reside in the high mountains of the Caucasus, the Pamir, and Tibet,
where the natural radiation background is very high — “as high as in the zone after the acci-
dent.” Not realizing that the effect of the sun’s rays is different from the effect radioactive io-
dine or strontium has on the human body, quite a few persons accept the “small dose” idea in
the usefulness myth as reliable.

Many have now managed to find confirmation for this set of beliefs in the surrounding re-
ality. For example, samosyely, those people who had not left the zone when resettlement else-
where was common (or who rapidly returned) and have been living in the zone ever since,
claim that their neighbors and relatives who were resettled “are all dead now, while we are still
alive and kicking.” Obviously, such statements reflect the actual state of things to a very limited
degree! However, they serve to confirm the population’s belief that their attitude towards the
outcomes of the disaster is right.

The pessimistic pole is represented by the death myth or the notion of all-penetrating ra-
diation. This cluster of beliefs is based on the assumption that only a thick layer of lead and
concrete can completely shield an individual from radiation, so that there can be no total protec-
tion in ordinary life. The extreme form of this attitude is to be found in the black humor that
became so popular after the accident. As a reflection of this myth, supposedly “authentic” sto-
ries of five-legged hares, double-headed cows, electromagnetic fish, etc. came into being. Over
the past 15 years, this latter set of ideas has undergone substantial transformation and it now
mainly exists in the *myth of painful diseases and eventual but inevitable dying*.

In 1998 the Institute of Psychology carried out a survey in which we tried to identify the public’s views of the consequences of the Chernobyl accident. The first question was aimed at learning whether people still felt the impact of the accident. (1) The sample was 2400 people who formed a cross-section of the community population in regard to age, sex, economic status, etc. The results obtained are shown in Table 1.

### Table 1

Intensity of Individual Emotions Related to Effects of Chernobyl (percent)

<table>
<thead>
<tr>
<th>Intensity of Emotions</th>
<th>School Children</th>
<th>Adults</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strong emotions</td>
<td>19.3</td>
<td>52.4</td>
</tr>
<tr>
<td>Insignificant emotions</td>
<td>43.3</td>
<td>31.6</td>
</tr>
<tr>
<td>No emotions at all</td>
<td>37.3</td>
<td>16.0</td>
</tr>
</tbody>
</table>

These data indicate that 84 percent of adults and 62.7 percent of children believe that they still can feel the effects of the Chernobyl nuclear power plant accident, regardless of what any objective measurements might indicate. One can assume that these perceptions are more significant for the individuals residing in the afflicted areas than any objective data describing actual radiation/environmental effects.

To get additional information on this last point, all respondents were asked a specific question about exactly how these perceived effects were manifested in them and in their families. The results are shown in Table 2.

### Table 2

Percent of Respondents Indicating Various Effects of the Accident

<table>
<thead>
<tr>
<th>Manifestations</th>
<th>School children</th>
<th>Adults</th>
</tr>
</thead>
<tbody>
<tr>
<td>We get sick more often</td>
<td>53.5</td>
<td>62.8</td>
</tr>
<tr>
<td>We lost everything at the time</td>
<td>3.0</td>
<td>6.5</td>
</tr>
<tr>
<td>We constantly keep in mind</td>
<td></td>
<td></td>
</tr>
<tr>
<td>everything related to the accident</td>
<td></td>
<td></td>
</tr>
<tr>
<td>and to radiation</td>
<td>27.4</td>
<td>34.0</td>
</tr>
<tr>
<td>The whole way of life has changed</td>
<td>9.9</td>
<td>14.6</td>
</tr>
<tr>
<td>Others</td>
<td>16.2</td>
<td>2.7</td>
</tr>
</tbody>
</table>

The data given in this table show that adults believed there were four major effects. The
school children enumerated a number of other manifestations that basically were variations of those already mentioned. For example, “We had to move to another place,” “I can’t do physical exercises,” etc. The most significant fact is that both children and adults highlighted the psychological impact of the accident. It is noteworthy that the supposed increased sickliness cannot be due to actual radioactive effects. More than 75 percent of these respondents had always lived in areas not affected by any substantial radioactive contamination. Therefore, the references to the increased morbidity (sickness) level, for most persons, reflect a neurotic-like concentration on individual psychophysiological somatic conditions. Moreover, a significant number of answers explicitly referred to the psychological consequences. Also of interest, the material losses caused by the disaster were not an important component in the psychological evaluation of an individual’s present condition.

Everyday life provides people with a good deal of information supporting the death myth (or to put this another way, the sickness myth.) In their search for facts supporting their beliefs, people frequently make comparisons: What they are today to as against what they used to be before the accident; what they are today as compared to their parents, children of today versus children of the early 1980s, etc. Every time such a comparison takes place, they are sure to find the traces of aggravations, deterioration, weakening. Some typical examples are:

- Women often say “I used to be strong as a horse and my mother remained a real beauty until the age of sixty. Now I feel I have no strength left in me; my hair is totally gray; I am fed up with everything.” Even as they say this, they “forget” that they will never see age 50 again and that a mother’s image is usually embellished by her children.

- “In our village nobody has ever been sick and now people have become so weak and sickly it breaks one’s heart just to look at them.”

But as the interview continued, we often found that their village never had any medical facility or specialist, let alone a hospital. All they had was a nurse and all diseases were cured at home with “time-tested Granddad’s methods.” Nowadays, when all the children are required to be examined by medical staff twice a year, parents have a better chance to learn about their children’s diseases and tend to blame radiation for all of the physical problems.

As was mentioned previously, the myths of usefulness and of death can be seen as lying at the two opposing poles on a gradient of optimism versus pessimism. A set of beliefs regarding chance can be located in the middle of this continuum. This last-mentioned myth is based on
the widely-held assumption that individual choice matters little and that a human life is predetermined by fate (doom) or by a combination of random factors. Our culture has a great number of proverbs, sayings, and tales reflecting this idea. Indeed, the notion of “chance” can be developed into a worldly philosophy that can help one to survive in the most overpowering and complicated situations. When the major factors influencing people’s lives seem out of their personal control, their notions of “chance” or “fate” can preserve hope for something better and help them cope with their powerlessness. On the other side, though, the concept of “chance” engenders passivity in that it does not call for any action by the believer. The characteristics that account for the wide popularity of the “chance” concept in relation to the consequences of Chernobyl are as follows:

1. the consequences cannot be managed;
2. therefore; attempts to control the consequences are pointless;
3. protection is useless. What a person can do instead is to put up with the consequences, to lay low and wait, and hope for something better.

The passivity arising from such a set of beliefs can, perhaps, account for the fact that immediately after the accident (and in the years following), the number of people who think they have little personal control over what happens to them (i.e., who have a sense of external locus of control) has been growing. Social apathy, lack of individual initiative, dependent attitudes, and other manifestations of externality have become one of the most acute problems for communities and perhaps for society as a whole.

Our research has also shown that these “attitude” myths are amended by “action” myths. We can think of these latter views as lying along a continuum of active versus passive behaviors regarding the problem of radiation. The active extreme is represented by the “protection myth.” This pole envisions a whole range of actions aimed at protecting individuals from radioactive effects. Closing the windows and the window panes; keeping windows shut as long as there is radioactive dust in the air; taking a shower at least twice a day; washing and cleaning footwear frequently; covering your head and body; not bathing in water reservoirs; not sunbathing, etc. are recommended actions. Another set of rules at this active end of the gradient deals with evacuating radionuclides from the body: drink as much liquid as possible; eat carrots; drink a lot of dry red wine; eat garlic every day, etc.

However, all these beliefs prescribing action have their own peculiarities and limitations. First of all, many of us do not understand what we are protecting ourselves against when we
undertake the advocated behaviors. Even now, more than 90 percent of the population is unable to provide the definition of either radioactive elements or of radionuclides, and few actually know how this or that recommended action is related to types or levels of radiation and what would be the effects of each specific action. And in addition to all this, the number of all possible recommendations is so huge that it is impossible to follow all of them! We have never found a scientific research study that tried to generate, analyze, and put together all the recommendations published during the fifteen years since the Chernobyl disaster.

All these factors question and seriously weaken an action-oriented psychological structure. An individual undertaking a presumably protective action does not see the final result and it is not possible to assess any action’s actual effectiveness. Moreover, control over all that is occurring does not seem feasible. This means the protective actions basically are “magic” actions with their roots deeply in a mythical consciousness. Instead of being a truly rational and effective system of behavior in an emergency situation, they are a form of irrational adjustment and adaptation to an incomprehensible reality.

Nonetheless, the recommendations are often accepted and carried out because of a trust in the source of the information. (2) As a notable example, immediately after the accident, it was common to hear some persons say such things as “A physician I know told me to use only detergents instead of soap because detergents contain alkali.” These statements were made even though the speakers did not remember from their secondary school chemistry what “alkali” were, or how this material might affect the consequences of exposure to radiation.

With all of the uncertainty confronting them, people frequently fall back on familiar actions as the only right and reliable courses of behavior. Hallowed by tradition and routine over the years, the actions’ performance acquires value independently of the actual outcome.

Opposite to the beliefs favoring activity are the views essentially advocating passivity, such as the “take it easy” myth. This particular cluster of ideas is based on the assumption that there is no real or effective protection against radiation and that the use of any drugs or actions leads only to fixation on the problem and to the development of a permanently stressful condition. The myth may be a form of psychological defense against the stress situation. If we pretend it’s not there, perhaps the situation will cease to exist.

This myth has undergone substantial changes in the years following the disaster. In 1986-87, it had a definite hedonistic tint, and many persons seemed to think that “while we are still around, we’ll enjoy life as much as we can.” This behavioral model can best be described as “feast in the time of plague.” In the course of time, however, people apparently increasingly came to believe that few had died and that health had not generally deteriorated. They also realized that one had to earn one’s living and raise one’s children. The hysterical component of the
myth was eventually replaced by calm resignation as far as the radiation factor was concerned. “Let’s live as though it had never happened” was the main theme of this set of beliefs. People obviously are aware of the accident and its consequences, but they don’t see any point in “re-opening the wounds.”

This myth is very important because it makes people feel quite safe and comfortable. They can believe their familiar picture of the world is not falling apart, and that they can preserve their traditional system of values, life objectives, and expectations. It is as if they think only a passive attitude towards unmanageable and uncontrollable extreme factors enables them to preserve a constructive stand toward life as a whole and a high level of internal locus of control. (3)

The myth of chance can be located in the middle of the active-versus-passive continuum. Basically, this is the pattern of views we described before in talking about the “chance” ideas on the optimism-versus-pessimism dimension. However, this version of the chance myth has little to do with whether or not one should do something definite to reach a particular goal. In this instance, people emphasize the fortuitous (lucky) results of their behavior, rather than the fortuitousness of life as a whole. “Of course one should act somehow, but God only knows what will come out of it” is a typical expression of this behavioral pattern.

If we take a very broad (and somewhat simplified) look at the clusters of beliefs (or myths) that I have summarized so far, we can summarize their relationships schematically as in Fig. 1. What we have here are the forms of consciousness and behavioral patterns having to do with the consequences of the Chernobyl accident.
In a sense, the sets of beliefs at the ends of the proposed continua constitute the extreme and relatively “pure” forms of consciousness and possible behavioral patterns. There are also frequent blends of two or more of these five basic myths established by combining them psychologically. Our impression is that individuals with such a “blended” consciousness are more common than those with “pure” forms of consciousness.

But to proceed, the upper right quadrant refers to a behavioral pattern that can be formulated as: “Follow all recommendations and you will live to be 100 years old, untouched by any radiation.” In general, this is the most active and productive behavioral pattern in the face of radiation hazards. Nevertheless it has two serious drawbacks. For one, quite a few persons are often “fixated” on fulfilling all the recommendations, even though they may be controversial or contradictory. For such people, their whole life consists in following recommendations and all other interests and values become secondary. Also, some people become really certain that if

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they obey all the prescriptions they will eliminate the risk of all diseases. If they subsequently become sick, the sickness is a psychological trauma for them, regardless of the real nature of the illness or disease.

The behavioral pattern in the upper left quadrant can be described in these terms: “Try to avoid hazardous impacts even though it won’t help much.” An example comes from a conversation with a therapy client, an interpreter who often accompanies foreign delegations on their trips to the Chernobyl zone. She voiced the complaint that in recent years it has become more and more difficult for her to go to the radiation zone and that she feels deep stress and discomfort during the trips. The conversation went like this:

*Psychologist:* When was the last time you went out on the beach, or in the woods, or on the river?

*Client:* I remember the exact date. It was in April 1986, just five days before the disaster. I still think I was very lucky.

*Psychologist:* And after the accident, did you stay in Kiev all the time? (The client lived in Kiev.)

*Client:* Yes. Mainly. I could leave only for a couple of weeks, to stay with my relatives in the Poltava region. (4) But very soon my competent acquaintances provided me with all the necessary rules of behavior in situations of radioactive contamination. I followed the rules very accurately. I follow the main recommendations even now.

*Psychologist:* Many people are not afraid any more to go to the forest or to the beach or on hiking trips. Would you like to do this too?

*Client:* I would love to. I love nature very much. But I’m afraid I can up in a radiation spot. These people who go are not concerned about their own health.

*Psychologist:* A friend of mine goes every year to the Ministry of Emergency Situations to obtain a map of contaminated areas.

*Client:* Perhaps it is a good idea to have such a map.

*Psychologist:* Wouldn’t you like to have this map? The maps are available and are not confidential.

*Client:* No, I’m afraid.

*Psychologist:* Why?

*Client:* I am afraid that looking at the map will upset me even more. As it is I can assume that I am safe, at least at home. But I don’t know what I will see on the map and I am too nervous already!
This client demonstrates her persistent concern about her health. This makes her undertake certain protective actions, but as a result she is afraid of life as a whole.

In the lower left quadrant we have a behavioral pattern that can best be typified this way: “Before the accident, everything was OK. Now things have changed, but I can’t do anything about it.” This attitude is shared by a relatively small number of people. The behavioral pattern here is based on a deeply-held, irrational fear of any changes, along with anxiety about the destructive effect of radiation. Indeed, radiation anxiety permeates the whole life of these people and they are exceedingly passive. The main theme of their behavior and perception is to hide, to wait until life becomes the way it used to be.

Finally, the lower right quadrant refers to a behavioral pattern that can best be described as follows: “I don’t know what radiation is. I never saw it, but anyway, one should lead a normal life.” This behavioral pattern came into being only 4 to 5 years after the accident and is now rather common. The absence of visible evidence of the efficacy of various protective procedures and the subjective inability to live under constant fear account for the rapid growth in the number of people who share this pattern. Typically, this group is composed mainly of men 25 to 45 years old and adolescents 12 to 14 years of age. Life values and interests apart from radiation are priorities for them. Their good health and recent maturity produces an optimistic assessment of the environment and the radiation situation. The following statements are typical of this group: “Maybe radiation is there, I don’t know. But in the last ten years I’ve become a fit guy. I never get tired when I work. I can drink a bucket of booze. Perhaps it’s due to radiation. I wouldn’t know.” Many teenagers, in their hearts and souls, don’t believe in radiation at all. They tend to say, with adolescent omnipotence: “What do I care about radiation?!” As mentioned above, such an attitude is not very productive in dealing with radiation effects of the Chernobyl accident. However, it is most beneficial for the mental health and life-view of the individual.

Conclusion

The following points summarize this chapter:

• The special nature of the Chernobyl accident and the extreme complexity of its consequences have led to a situation in which the majority of the affected population have not yet developed a rational perception of radiation effects and their influence on human life and health.

• Under such circumstances, sets of beliefs, or “myths,” about the accident and its conse-
quences have created the foundation for behavioral patterns governing responses to the accident. Mythological forms of consciousness combine these clusters of beliefs with behavioral models and motivations.

- We have identified five basic myths that prevail in mass consciousness and identified the main forms of behavior associated with each myth.

- All the behavior patterns described are “adaptive” in that they help ensure survival in emergency situations. Nevertheless, these patterns do not provide an entirely adequate and complete understanding of the situation nor the tools enabling the individual to manage and control what happens in the changing situation. This is an unfortunate state of affairs. We can assume that one of the major factors underlying the total mythologization of behavior is a deficient and even erroneous system of informing and assisting the populations affected by the impact of the Chernobyl nuclear power plant accident.

- The mythologization of mass consciousness is in itself one of the adverse psychological effects of the Chernobyl accident.

- There is a need for research aimed specifically at developing a constructive behavioral pattern under conditions of radiation disaster. There is also a need to develop methods for training people in various walks of society in these patterns. These patterns can be created only by joint efforts of psychologists, sociologists, social workers, medical workers and radiologists.

These patterns can be developed and disseminated through the network of Community Centers for Social and Psychological Assistance that were created by UNESCO and now operate within the framework of the UN Chernobyl program.

(Editor’s note: Details of these Centers’ programs can be found in Dr. Garnets’ chapter and in Appendix B.)

Endnotes

1.1998 Survey, Institute of Psychology, Kiev, Ukraine

2. The issue of psychological mechanisms of trust toward the sources of information in situations of total mistrust toward official sources, becomes very significant and interesting, especially for programs dealing with controlling effects of accidents.

3. This conclusion is confirmed by results of our research on population behavioral patterns in situations of protracted social and economic crisis.

4. In 1986 the Poltava region was considered the safest region in Ukraine from the environmental point of view.
Chapter Thirteen

DEVELOPMENT OF A COMMUNITY-BASED SYSTEM TO PROVIDE PSYCHOSOCIAL ASSISTANCE TO THE VICTIMS OF THE CHERNOBYL CATASTROPHE (1)

Oksana Garnets. Ph.D.

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As other chapters in this publication have made clear, natural, technological, and social crises and disasters often have a serious psychological impact on the affected individuals. The 1996 international conference on Chernobyl held in Vienna emphasized that the psychosocial consequences of the disaster must be given as much consideration and study as is given to the radiation exposure. Psychological distress, it was noted, contributes not only to psychosomatic illnesses, but also to morbidity levels. (2)

The Chernobyl crisis has several major characteristics:

• Abrupt changes in living conditions, including possible change of residence;
• Change in the surrounding social environment;
• Breakdown of traditional and habitual relationships (including family relationships);
• The need to adjust oneself to new living conditions and situations;
• The need to confront and to solve newly-recognized existential problems (e.g., such as questions of “why did this happen to me?”);
• The need to adjust to the breakdown of values that previously governed daily life.
The Chernobyl disaster also forces individuals to face the loss of belief in his/her potentialities. This sense of loss engenders what may be termed a “victim syndrome,” characterized by feelings of pessimism and victimization, often followed by social withdrawal and an unwillingness to be responsible for one’s life.

For example, in 1999, the portion of the affected population that manifested the victim syndrome had doubled since 1992. In 1992 the feeling of victimization was expressed by 18 to 20 percent of the population sampled, whereas by 1999, this percentage had increased to 35 percent. The majority of those who demonstrated this victim syndrome (80 percent of them) were those who were relocated from the highly contaminated 30-kilometer zone close to the nuclear power plant. Of those still residing on contaminated land, only 20 percent regarded themselves as victimized. These figures imply that a major factor in feelings of victimization were changes in traditional life conditions and life styles that were required following the disaster.

The developments arising from the disaster—such as resettlement, restrictions in the production and consumption of agricultural produce, receipt of controversial information, incomplete or incorrect assessment of the possible consequences of the disaster—led to drastic changes in traditional life styles, especially in the case of the rural population. Lack of knowledge about radiological protection keeps them from assessing the trustworthiness of information distributed by the mass media and results in subjective and unrealistic evaluations of the disaster’s consequences. [Editors’ Note: All of these matters are discussed in other chapters of the present book, especially in the chapters by Shvalb, Speckhard, and Tykhyy. Speckhard’s chapter places considerable emphasis on the role of the victims’ understanding of the calamity and its aftermath.] Data from the 1999 investigation show that 45 percent of the people residing in the contaminated zone and 30 percent of those living in clean zones believe that whatever ill health they have is due to radiation.

Despite the fact that the Chernobyl accident happened more than 15 years ago, it remains a source of distress. This continuing sense of helplessness, despair, and loss of hope for the future is also apparent in the results of yet another survey of 2400 people in the affected areas, conducted in March 1998. [Editors’ Note: Shvalb’s chapter also refers to this survey.] Among the adults questioned, slightly more than half answered that they still feel the consequences of the Chernobyl catastrophe strongly, and almost another third experience the consequences to some extent. Among the children surveyed, 19 percent said they strongly feel these aftereffects.

This perceived stress, not unexpectedly, has engendered a number of negative psychological consequences, such as various emotional disorders, distortions in reality perception, and the disintegration of psychological mechanisms that generally regulate human activities. And so,
there has been an increase in “non-constructive” attempts at coping—such as alcoholism, drug usage, and criminal behavior (especially among adolescents) as well as suicides. In Slavutych, a new town of 26,500 people built in 1987 to house personnel who continued to work at the nuclear power plant, as just one example, 29 percent of the adult population and about 15 percent of adolescents have drinking problems. Yet other manifestations can be seen in the decline in the general level of tolerance underpinning interpersonal and intergroup relations and the considerable jump in other negative developments in virtually every sphere of community life, including an increase in divorce rates and the number of abandoned children.

Overlaying the stress-induced reactions are some psychological features resulting from life in post-totalitarian countries. The totalitarian governments’ paternalistic practices can lead to passivity and social inactivity in their citizenry, and as a consequence, these people may have great difficulty developing positive coping strategies aimed at reducing the stress they experience.

All in all, it is now quite obvious that people victimized by a catastrophe require psychological, as well as material assistance. In the case of those afflicted by the Chernobyl accident, however, there were no adequate institutions in place that could deliver this type help to the population, either at the individual or the community level. In fact, the social infrastructure existing at the time of the calamity did not pre-suppose the need for any psychosocial services at all. Yet another problem enhancing the difficulty of providing the desirable assistance is that the accident’s psychosocial aftermath has been—and still remains—both underestimated and not well understood. Many of the analyses of these aftereffects have been based, in an oversimplified manner, on the conception of the “posttraumatic stress disorder syndrome.” However, the Chernobyl catastrophe’s consequences do not fully fit this syndrome as it is usually described. Rather, we can say that these reactions reflect a long-term distress condition produced by a multiplicity of individual and social factors. A number of experts participating in a 1996 conference on Chernobyl in Vienna recognized these diverse contributors to the calamity’s aftereffects when they emphasized the needs to: (a) increase public knowledge of the health effects of radiation and radiation protection; (b) foster people’s faith in their personal ability to change one’s life for the better; and (c) show the affected people the necessity of themselves undertaking steps at the local community level to improve their lives.
Establishment of the UNESCO-Sponsored Community Centers

As the Chernobyl victims’ many needs became increasingly apparent with the passage of time, in 1991 to 1992, the UNESCO-Chernobyl program began to develop a network of Community Centers to serve the populations severely affected by the catastrophe. This project was, and remains, the first and only intervention of the kind needed to develop the types of community institutions necessary to address the social and psychological aftereffects of this type of disaster.

The Centers’ Purposes and Objectives

The Centers established were to provide psychological support by delivering psychological assistance to local residents individually and in groups, and also, by developing the community residents’ capacity to solve their problems and cope with the crisis by themselves. The Centers’ objectives, as initially specified, were to: (a) improve the mental health of all age and social groups in the community; (b) encourage interactions within the community; (c) empower community members to take control over their lives; (d) develop social responsibility; and (e) enhance problem-solving skills in individuals and groups.

The Centers’ planned programs were to deal with every area of community life. Programs included individual, group, and family counseling; support for groups confronted by serious social problems, as well as those “at-risk” for significant difficulties; play centers and creative activity rooms for children and adolescents; education activities (including computer skills and sport activities) for all age groups; information and publishing activities; and community action. Guided by concepts and values inherent in social work, and community and clinical psychology, the work is grounded on community needs assessments.

Significantly, members of the staff were initially called the Centers’ “Centers of Trust.” It was important that these institutions not be associated with official authority in the minds of the people, but perceived as belonging to the community.

The Nature of the Centers

From 1994 through 1997, a network of ten Community Centers for Psychosocial Rehabilitation was developed in affected areas of Russia, Ukraine, and Belarus within this framework of the UNESCO-Chernobyl Program. By the year 2001, three new Centers had been added.

The Centers’ work in the communities is linked in various ways to the disaster’s conse-
quences. And so, five of the Centers are in contaminated zones; another is at a site constructed for those resettled from communities in the “dead zone” near Chernobyl; three are in mixed communities of both “locals” and “resettled” populations; another Center is located near the Chernobyl power plant and houses people working at the plant since the disaster; and yet another one operates on the grounds of the Clinic for Radiological Medicine and Rehabilitation outside Minsk and serves all children with thyroid cancer and disorders in Belarus.

Given that psychosocial services and professions with appropriate backgrounds did not exist at the time of the disaster, UNESCO re-trained people in relevant professional occupations specifically for the Centers’ work. The persons chosen for this training had educational or academic psychology backgrounds but received about 1200 additional hours in counseling, stress, coping strategies, community psychology, and social work. This training program was designed by international experts and refined by national professionals. The UNESCO staff trained to work in these Community Centers were, in fact, the first to practice community social work in countries of the former Soviet Union. More importantly, this cadre is now training the next generation of professionals to provide similar services in communities throughout Belarus, Russia, and Ukraine. Their experience has also been used in work on resettlement problems in the Crimea.

The Centers were at first intended to have only a comparatively limited scope of activities: those seeking to reduce the community residents’ fears regarding the negative influence of radiation on health and improve their adaptation to their new living conditions and changed social environment. Dissemination of accurate information was regarded as an important function and as a means of lowering the population’s anxiety. The main focus was on children and families.

Since each Center operates in a specific community, they have to develop specific programs appropriate to the needs and problems in this community. But in addition, operating as a network, they face the whole scale of Chernobyl related psychosocial problems. With the communities’ needs and expectations changing as time goes by, the Centers’ programs are often updated, requiring them to assess the residents’ attitudes and wants, fairly frequently using various types of psychosocial and sociological surveys. This activity allows the Centers’ staff to develop targeted programs aimed at the achievement of specific objectives. It also enables them, through consultation with other social services and local governments, to identify and anticipate emerging problems.

For example, as a result of a community poll, the Center in Borodyanka, Ukraine, developed a support program that examines both medical and psychological concerns of young women afraid of having children because they live in a contaminated area. This Center also es-
tablished an educational and psychological program designed to prepare young children for entry to school. At the Strechin Center in Belarus, a specific program was developed to lessen the frictions within the community, which was split by confrontations between the local (or indigenous) population and the newly acquired “resettled” people from Chernobyl. In Slavutych, Ukraine, a hotline was established as psychological tensions began to rise due to the imminent closure of the Chernobyl nuclear power plant. Other requests from communities resulted in Center programs for business training, and support to invalids as well as the families of “liquidators” (firefighters who put out the nuclear fire), along with the creation of various nongovernmental, volunteer organizations to address community problems.

Many of these activities testify to the important role community-related functions can have in promoting mental health improvement in the post-catastrophe period. Thus, the Centers are now closely involved in community development programs and activities in cooperation with other institutions such as schools, hospitals, and orphanages and with local government administrations. In addition, members of the community are participating as volunteers in various activities. Responsibilities are being placed on them to prepare and carry out important community events or to be individually responsible for some specific activities. This type of involvement enables community residents to develop personal contacts within the community that can aid in restoring social links that had been disrupted, and also importantly, helps foster individual initiative and responsibility. In sum, in addressing their communities’ needs, the Centers’ functions have resulted in a substantial expansion of community life in those domains they serve.

As a notable example of the Centers’ role in aiding community development, the essential need for economic improvement prompted most of the Centers to establish various types of business training programs for different age groups covering such matters as the economic aspects of small businesses and/or the creation of small enterprises. These programs also encourage people to develop individual responsibility and initiative. Still another example is provided by the Slavutych Center. Faced with the closure of the Chernobyl nuclear plant, this Center established a number of programs to help with individual and community problems emerging under new social and economic conditions.

Another major area of the Centers’ activities deals with public information. Besides conducting meetings providing information on important issues, the Centers have also helped generate publications by community members dealing with such matters as the local ecological situation and ways of obtaining better protection against radiological contamination (such as in food preparation). Some of these publications are prepared and illustrated by children, others
are magazines for young people, and so on. The publications are produced mainly at the community’s request and are distributed for free, an important consideration given the current economic conditions.

Thus, community-based psychosocial rehabilitation deals with the following problems:

- Reduction of general tension and anxiety among populations suffering from the aftermath of the disaster (liquidators, resettlers, residents of contaminated territories, etc.);
- Psychological support to individuals and families facing marital and family functioning issues, learning difficulties, health issues, etc.;
- Consultation to school administration and staff who work with parents and children regarding effective parenting skills;
- Public information and publishing activities;
- Psychological support to socially unprotected groups of the population and so-called at-risk groups such as the liquidators, alcohol and drug addicts and their families, young mothers and pregnant women, invalids and their caregivers, the elderly, families with many children, single mothers, etc.;
- Work with unemployed people to help individuals develop the willingness to undertake an active search for a new job and employment; or to start a small business.

_Evidence of the Centers’ Popularity_

In the first six years of their operation, the Centers have proved to be both necessary and efficient institutions. With people from a variety of backgrounds participating in many different activities, the number of visits is constantly increasing. The statistics for the Center in Ivankiv, Ukraine, are illustrative. Even though this Center serves an area of only about 13,000 people, it has received more than 37,000 visitors since it opened. Within the first six months of 1996, there were 6,907 visits to the Center and this increased to 9,878 visits during the comparable period in 1999. In the Centers overall, in 1998, four years after the first Centers opened, there were 151,480 visits, whereas in 2000, with only ten of the Centers reporting, the number of visits climbed to over 165,000.

The Centers’ popularity is also indicated by the large proportion of community residents taking part in Center activities of one or another kind. In this case statistics show that, especially in smaller communities, a majority of those residing in the area served by a Center has been involved in Center activities in some way. A 1999 survey conducted by the Centers, with responses from 469 persons, found that half of the adults in the sample visited their regional
Center either “very often” or “regularly.” Of school age respondents, 58 percent visited “very often” or “regularly.”

In the same survey, respondents were asked, “Do you think the Center’s performance caused any changes in the life of your town or village?” The results are summarized in Table 1.

### Table 1
Evaluation of the Centers’ Impact on Community Life

<table>
<thead>
<tr>
<th>Extent of Influence</th>
<th>Local Officials</th>
<th>Adults</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strong influence</td>
<td>60.9 percent</td>
<td>27.2 percent</td>
</tr>
<tr>
<td>Average influence</td>
<td>32.6 percent</td>
<td>57.5 percent</td>
</tr>
<tr>
<td>Light influence</td>
<td>6.5 percent</td>
<td>9.4 percent</td>
</tr>
<tr>
<td>No influence</td>
<td>0</td>
<td>6.9 percent</td>
</tr>
</tbody>
</table>

This indicates that about 90 percent of the people in the areas served by the Centers agree that these institutions have a decided influence on community life. Local officials evaluate this influence even higher than the population and we can assume that they have a more comprehensive understanding of social processes in the community.

Centers have become part of the social and psychological infrastructure in their communities. Because the Centers provide cultural and leisure activities that are of great importance for community life as experienced by all members of the community, people are highly satisfied with Center activities and are interested in their future development.

The Centers also remain important to all communities they serve because they address the long-term consequences and the humanitarian dimensions of the Chernobyl disaster. These long-term consequences are as important as the needs requiring assistance immediately following a disaster. Such long-term assistance must focus on helping people develop positive coping strategies, on building people’s capacity to reconstruct their lives, and on restructuring of communities affected by disaster.

Long-term assistance, such as that provided by the Centers, assumes in part that personal problems are a reflection of the problems of the community as a whole and relies heavily on mechanisms of mutual support and empowerment. Thus not only the individual, but the community as a whole, benefit from personal involvement of its members in community life.

Due to the juxtaposition of the Chernobyl accident with the collapse of the Soviet Union, the Centers have accumulated unique professional and organizational experience of how to work effectively in a post-catastrophe period complicated by severe social and economic crises.
The success of the Centers in achieving their objectives is to a large extent conditioned by the specific strategies and methods applied in their operation.

- The philosophy of the Centers is not just to deliver assistance to the affected population but to empower people to act independently; to foster self-responsibility and social responsibility among those who consider themselves victims and who are experiencing pessimism and inactivity.

- In addressing the psychosocial problems of the affected population, a major effort was made to build up and develop disrupted communities and to re-establish community-based mechanisms of mutual assistance and to develop civil society components such as community oriented non-governmental organizations.

- The crises experienced by the population suffering from Chernobyl consequences are of a multi-model nature (ecological, social and psychological, etc.), so the nature of Center activities is multidisciplinary in character. For example, education and information programs are focused not only on the consequences of the ecological disaster but also on disaster prevention and preparedness issues.

- Both the populations of the communities and the local administrations now accept the need for social and psychological support. They consider social work oriented toward providing help to groups of people affected by Chernobyl as an important aspect of community functioning.

- Activities of the Centers promote positive changes in the development and consolidation of communities.

An important aspect of the Centers’ work has been a wide acceptance of the philosophy of delivering professional psychosocial assistance to people in need. However, the tasks and issues the UNESCO-Chernobyl Centers are dealing with are much broader than coping with the consequences of the Chernobyl catastrophe. The populations of the newly independent states of the former Soviet Union are suffering from psychological crises caused not only by Chernobyl effects but by serious social and economic changes that have resulted in increased unemployment, impoverishment of large populations, a decrease in access and quality of medical care, etc. These factors make it impossible to separate the Chernobyl psychological consequences from consequences caused by destruction of the broader social and economic system.

In establishing the Community Centers, UNESCO was the first international organization to face the most complicated and long-lasting consequences of the Chernobyl catastrophe. The expertise accumulated by the Centers is in a way unique in that they were established after emergency disaster relief had been successfully provided by such agencies as the Red Cross.
immediately following the accident. After this acute phase of a disaster is over, however, people must adjust themselves to a different life and a different environment. International emergency relief organizations are not geared for this long-term phase and work in this secondary phase has not been generally promulgated and analyzed.

The work of the Centers has spawned development of new professions. Clinical psychology and social work did not exist in the former Soviet Union. The Community Centers’ training program has focused on new ways of developing and experiencing “community.” It is changing the way people interact with each other and with their legitimately elected government officials.

The work of the Centers, and the training programs set up to prepare professionals for this type of community development and psychosocial work, has spawned new curriculum in higher education programs at Kyiv National University in Ukraine, Vitebsk State University in Belarus, and in several other institutions. The Centers offer their sites as training centers and their staff as participants in these developments.

In their brief lifetime of just over six years, the Centers have had three evolutions: from crisis intervention and public information centers and support centers for communities and populations severely affected by the Chernobyl nuclear disaster, to advocacy and education centers, to community development centers. This network of Community Centers for psychosocial rehabilitation has proved to be an efficient tool for delivering psychological support under conditions of long-term distress that might be applied to different types of crises in communities. The Centers have pioneered new ways empowering individuals and groups and local government that differ from the strict hierarchical processes previously utilized by the Soviet government. They have helped develop the professions of social work and community development and clinical psychology in the newly independent states of the Soviet Union. They are now the consultants and trainers to a second generation of new professionals working to prepare people of former Communist countries to live as citizens in a more democratic society.
APPENDIX

(Editors' note: This information was provided by UN Chernobyl Programme Office, Kiev, Spring 2001)

Ukraine

Borodyanka. The population of Borodyanka and the Borodyanka Region amounts to 57,500, including 8500 resettlers and evacuees from the Exclusion Zone. The Centre’s staff is comprised of 13 specialists (social workers, psychologists, activity organizers, day-care workers) who work with all age groups.

The Centre’s main activities are:

• Maintaining the Rescue School on which the All-Ukrainian Adolescents Rescue Movement has been created;
• Ecology laboratory;
• Information activities, including “Truly Yours” analytical magazine, “For You” information bulletin, and “World of the Child” monthly magazine, etc.
• Individual and group consulting;
• Group and mass activities, etc.

There were about 19,500 visits to the Centre in 2000, including 15,700 by children and adolescents.
Ivankiv. The population of Ivankiv is 11,300. It is located in a rural area. The Centre staff includes 10 specialists.

The Centre’s main activities include:
- School of Health
- Public Information services
- Individual and group consulting
- Group and community events, etc.

Special attention is paid to work with re-settlers (people moving back to the contaminated zone), disabled children and old people. The Centre’s specialists have also worked out a programme for studying national and local traditions and customs. They also support the local “Children’s Home” for orphans, where they deliver the “Nadezhda” (Hope) programme. The main goals of this program are the orphans’ optimal mental heath and individual growth and development.

The number of visits during 2000 was 20,896, including 14,346 by children and adolescents.

Slavutych was built in 1987 for employees of the Chornobyl power plant and their families. The population of the city of Slavutych is 26,500. The Centre’s staff includes 8 specialists.

Pilot programmes and on-going projects include:
- Monitoring public opinion regarding the population’s acquaintance with town and country problems; inhabitants’ confidence in local government, youth problems, etc.
- Sociological polls;
- Training for teachers and psychologists of Slavutych institutions;
- AIDs, alcohol and drug preventive projects;
- Work with elderly people;
- Week-end school for adolescents;
- Child and family abuse;
- Consulting with other community groups and services, etc.

In 2000, the Centre had 17,727 visits, including 10,803 by adolescents and children. Increasingly, this Center’s work will involve problems arising from the closing of the last reactor on the Chernobyl site. Most of the citizens of Slavutych have been employed at the nuclear power
plant or provide services for plant workers and their families.

Boyarka. Within the framework of UN Chernobyl Programme and in close cooperation with the Ministry of Emergencies, a Centre for Social and Psychological Rehabilitation will be created in Boyarka. It will be a unit of the oblast (regional) hospital that provides treatment for children and adolescents living on contaminated territories of Kyiv Oblast. The annual number of hospital patients is 45,000.

The staff has already been hired for the Centre and have already passed a number of training sessions delivered by UN Chornobyl Programme Office. Currently this staff is studying the social and demographic situation in Kyiv Oblast, the population’s needs and demands for social and psychological services, and informing the population about the Centre’s objectives and tasks, etc.

The Centre’s specialists are working in close cooperation with hospital professional staff to work out strategies of further joint activities that will provide effective treatment of hospital patients.

Korosten. The population of Korosten and Korosten Region is about 110,000. The region is characterized by a high level of migration caused by the Chernobyl catastrophe. Over the last ten years, about 30,000 people left Korosten and about 20,000 of them returned because of dissatisfaction with living conditions in areas of their resettlement.

The Centre started its work this year. At the moment, the ten people on the Centre’s staff work in temporary facilities. Reconstruction of permanent facilities is going on and should be completed next year.

The main activities of this Centre will be:

- Programmes on drug, alcohol and AIDS prevention that involve volunteers who used to be drug addicts;
- Sociological polls;
- Providing the population with information about the consequences of the Chernobyl catastrophe and recommendations on how to minimize these consequences.
Russia

**Gagarin.** The population of the town is 31,000, including a number of resettlers from contaminated areas. The Centre’s staff consists of 12 specialists.

Pilot programs include:
- Consulting on issues related to developmental psychology; family and individual consulting; children’s psychological abandonment; etc.
- Working with at-risk groups;
- Social support of maladapted adolescents;
- Psychological work and consultation regarding juvenile delinquents;
- Work with disabled children and orphans;
- Work with poor families.

In the year 2000 there were 47,189 visits to the Centre.

**Bolhov.** This town, with a population of 13,000, is located in a contaminated zone. The Centre’s staff includes 12 specialists.

The Center’s main objectives are:
- To provide information services for the population and for municipal institutions;
- Social and psychological monitoring;
- Work with liquidators;
- Hot lines, etc.

In the year 2000, 5,080 people visited the Centre.

**Nikolskaya Sloboda** is a settlement that was built for evacuees from the Chernobyl zone and for liquidators and their families. The population of the town is 800 people but the Center’s staff of 19 specialists serves the Region. In several outlying villages, special psychological units have been created where the Centre’s specialists are working.

Main activities are:
- Social and psychological support to families with many children and families with one parent;
- Work with elderly people;
- Sociological polls;
- Social and psychological support provided through the mail and publications;
•English for children from 3 to 10 years old, etc.

In the year 2000, there were 2,380 visits to the Centre.

Uzlovaya is located on contaminated territory. Its population is 72,000. The Centre’s staff includes 19 specialists.

The Centre’s main objectives and target groups are:
• Work with children;
• “Parent–child relations” and “teacher-child” relationships;
• Work with liquidators and their families;
• Risk groups (orphans, children whose parents are alcohol addicts, etc.)
• Minimization of psychological and emotional tension among various groups in the population;
• Cooperation with municipal institutions aimed at local initiatives and development, etc.

The Centre’s specialists provide individual diagnostics; deliver sessions of fairy tale therapy and group art therapy, sociological polls, individual and family consulting, etc.

The Centre’s Programmes include:
• “World of the Child”
• “The Adolescent”
• “Parents Support Club”, etc.

In the year 2000, there were 11,470 visits to the Center, including 6780 by children and adolescents.

Belarus

Aksamovschina. This Centre for Social and Psychological Rehabilitation is on the grounds of the Radiological Medicine Clinic, the annual number of patients of which is 3000. The Centre’s staff includes 12 specialists who work with Clinic patients and with the community population of Aksamovschina (850 persons). The community population is comprised of Clinic staff members and their families.

Objectives of this Center include:
• Social and psychological examination of the Radiological Clinic’s patients and their further rehabilitation
• Social and psychological support of children operated on because of thyroid cancer and their families;
• Helping children to cope with fears of medical procedures;
• Development of children’s creative abilities.

In the year 2000, there were 15,355 visits to the Centre, including 13,570 by children and adolescents.

**Pershai** is located in a contaminated area but inside a so-called “clean zone.” The population of the village of Pershai and the nearby Region is 1900 people. The staff of the Center is eight specialists.

The Centre serves as a regional teaching institution for school psychologists and social workers. The Centre’s specialists closely cooperate with social services of Japan and are looking for collaboration with other Western countries and social institutions. Taking into account their rural location, the Centre’s main activities are:
• Educational group for school pupils and their mothers;
• Sewing sessions;
• Hairdressing saloon;
• Consulting services for individuals, families and groups, etc.

In 2000 the Centre had 14,925 visits, including 12,000 by adolescents and children.

**Streshin.** This settlement was built for evacuees from contaminated areas and is located in a so-called “clean” zone. The population is 1800. The Centre’s staff consists of five specialists.

The Centers’ main objectives are:
• Community consolidation
• Adaptation of evacuees to new living conditions;
• Professional orientation of the population;
• Information and public education activities, etc.

In close cooperation with the Streshin local authorities, the Centre’s staff publishes “Vestnik (Herald) of Streshin”, which is the region’s only newspaper.

In the year 2000, there were 10,450 visits to the Centre, including 8400 visits by adolescents and children.
Endnotes

1. This is a somewhat modified version of a paper originally written in 2001 for an earlier, and unpublished, version of the present volume. Dr Garnets is now at the United Nations Development Program office in Kiev, Ukraine.


3. Survey figures provided by UN Chernobyl Program office, Kiev.
Chapter Fourteen

CHERNOBYL IS HERE AND NOW

Norma J. Berkowitz

Norma Berkowitz was a member of the School of Social Work faculty at the University of Wisconsin-Madison for thirty years. Her book Humanistic Approaches to Health Care: Focus on Social Work was written for a Russian audience and published in Russian in 1999. As the founder and president of the Friends of Chernobyl Centers, United States, in March 2000, she was one of 32 Millennium Volunteers chosen and honored by the U.S. State Department Alliance for International Educational and Cultural Exchange.

Out of sight, out of mind.” Historical memory can be extremely short-lived, especially in modern times as television, newspapers, radio, and magazines repeatedly bombard us with reports of highly-dramatic occurrences, alarms about the latest domestic and international crises and problems, and news about whoever are the current celebrities. In spite of the emphasis on globalization and “one world,” for a great majority of the American public, the countries affected by Chernobyl exist only as vague images or at best, given the small proportion of Americans holding passports, as part of an unknown world. It is very easy to understand that the Chernobyl disaster, which happened in a country across the ocean and nearly 20 years ago, is widely viewed as having occurred “long ago and far away.”

The mass media’s failure to provide accurate information about the ongoing, complex issues arising in the three countries directly affected by the Chernobyl catastrophe helps foster this perception of the accident as having nothing to do with us. Events such as the environmental activists’ commemoration of the 10th anniversary of Chernobyl in 30 US states (1) and the international trek from Kiev to the Chernobyl nuclear site (2) were largely ignored in the American media. Those of us greatly concerned about the millions of people whose lives continue to be influenced by the Chernobyl disaster, and/or who greatly wish to find what lessons
must be learned from this unprecedented environmental event, find this attitude disheartening.

Other chapters in this book have discussed how and why the disaster occurred. This chapter provides examples of how various international and American organizations have responded to this catastrophe, and attempts to show that the Chernobyl disaster is still “here and now” to a considerable extent for many people not themselves directly affected by the accident.

In a talk given on April 26, 2004 dealing with the humanitarian needs arising from the Chernobyl accident, Jan England, United Nations Secretary for Humanitarian Affairs, told his audience that:

- 8.4 million people were exposed to radiation
- 5 million people still live in the affected areas
- 400,000 people have been resettled
- 90,000 square miles of land (half the size of Italy) were contaminated
- 18,720 square miles of agricultural land were ruined

The UN once estimated that it would take more than 200 years and over US $400 billion to totally remedy the adverse consequences of the Chernobyl nuclear accident. This cost will have to be borne to some degree by nations around the world. How is it possible that so many of us manage to put these costs and the fate of so many people out of mind even as the catastrophe’s impact affects our lives today?

**Steps Taken by Various Countries and the United Nations**

Immediately after the disaster, millions of US and European tax dollars were spent to re-train workers at nuclear plants in Russia, Belarus, and Ukraine. (3) Among other things, these funds were used to develop software that would help plant employees learn how to deal with nuclear emergencies. The money was also used to improve the Soviet-made nuclear plants in Eastern Europe, thereby making Europeans safer. On top of all this, in May 1989, about one hundred and forty electric utility organizations operating nuclear energy plants around the world met in Moscow and chartered the World Association of Nuclear Operators. This organization still exists to further enhance the safety and performance of nuclear energy plants worldwide. (4)
Shelter Improvement Project

A large part of current American investment focuses on building a new shelter to cover the remains of the damaged reactor on the Chernobyl nuclear power plant site. For months after the accident, as Tykhyy’s chapter in this volume relates, concrete and other materials were dumped on the ruined nuclear structure to put out the fire and dampen the radioactivity being emitted. With the passage of time, this cover, or “sarcophagus,” has come to require extensive repair and re-building. The dangerous work necessary in monitoring and strengthening this structure continues. According to Hans Blix and others, 200 tons of uranium and about a ton of radionuclides, 90 percent of which is plutonium, lie inside the existing shelter. (5) Investigators report “a luminescence characteristic of chain reactions inside the giant building.” (6) Should the existing sarcophagus collapse, there could be a second devastating Chernobyl disaster.

In addition to stabilizing, monitoring, and repairing the existing shelter structure, it is necessary to develop the infrastructure needed to support the construction of this new sarcophagus and to decommission the four existing reactors and to decommission three other reactors. All this keeps about 2000 people busy every day at the extensive Chernobyl site. The funds and effort necessary for these endeavors will have to be provided for a considerable time. The new president of Ukraine, Yuschenko, asked for additional US support in meeting these requirements in his address to a joint meeting of Congress during his triumphal visit to the United States in April, 2005. (7)

By the mid-1990s, danger of the existing shelter’s collapse was clear, and an urgent international project was undertaken to repair this structure. In 1997 the EU, US, and UK agreed to a US$768 million dollar, 8- to 9-year program to stabilize the structure. (8, 9) In 1999 the US pledge was $78 million. (10) By 2003, however, it became apparent that repair of the existing shelter (sarcophagus) would be insufficient to protect against another disaster. The European Bank of Reconstruction and Development (EBRD) agreed that an entirely new 20,000-ton steel structure, designed in part by America’s Bechtel Corporation, would be financed by a consortium of the Bank, the EU, the United States, and France. The new shelter will be the largest structure in the world--large enough to house St. Peter’s Cathedral in London. (11)

In 2004, on a FOCCUS-sponsored tour (12) of communities in Ukraine contaminated by radiation fallout, participants met at the Chernobyl nuclear power plant site with a representative from the Bechtel construction group. An extensive infrastructure (such as administrative offices, emergency evacuation buildings, staff showers and safety rooms, roads, railroads, and so on) must be completed before construction on the shelter can even begin. The complexity of the task is overwhelming.
Based on the approved actual design, cost estimates for construction of the new shelter have now risen from US$786 million to US$1.09 billion. (13, 14) Since the date of completion of the project is now several years behind schedule, costs will undoubtedly go higher. Funds must come from the Ukrainian national budget, the G-8 countries (which include the United States and Russia), and the European Union. The contributions pledged from outside Ukraine, however, may be dependent on unexpected economic and political events in the supporting countries.

Mismanagement is also a very serious problem. The European Bank for Recovery and Development, responsible for fiscal management of the project, has maintained that it is not clear which agencies and personnel in Ukraine are responsible for implementing the shelter project and indicates that this confusion has led to costly delays. A February, 2005, Ukrainian newspaper article proclaimed: “Chernobyl is two years behind schedule, with $300 million dollars overspent.” (15, 16) The chairman of the Ukrainian parliamentary Chernobyl committee reporting on these excesses has claimed that there is an overspending “on the shelter facility… of over 140 million dollars and on decommissioning (of the reactors) almost 170 million dollars and a time lag of almost two years.” In April 2005, the Kyiv Post indicated that the Ukrainian state-run company responsible for decommissioning the plant was in debt over US$6 million for electricity, gas, fuel, and transport.

Serhiy Osyka, chairman of Ukraine’s parliamentary ad-hoc committee investigating the effectiveness of state management agencies on the power plant site, has charged that corruption has been a major impediment to the construction work at Chernobyl. Adding to this indictment, on the 19th anniversary of the disaster (that is, in 2005), the deputy prime minister of Ukraine urged investigators to scrutinize carefully the “enormously big sums” paid to consultants and experts involved in environmental safety work at the plant. Prosecutors reportedly have launched a criminal case against an as-yet-unidentified person, as well as several private firms for the alleged misappropriation of US$165 million of Chernobyl money. (17) Some American tax monies, and certainly some of our American contractors, will be hit as this tale unfolds further. In spite of these difficulties, the Ukrainian government stated in the late spring of 2005 that it hoped to raise 300 million dollars in additional funds from other countries.

There also are other possible instances of corruption linked, directly or indirectly, to Chernobyl and the nuclear power industry in the former Soviet Union. In one of these troublesome cases, the Russian who headed the Moscow institute that designed the Chernobyl-style reactor has been charged with “multiple counts of fraud and money laundering.” Yevgeny Adamov, Russia’s former atomic energy chief, has been accused of stealing up to $9 million from the US
Department of Energy that was supposed to be used to improve Russian nuclear safety. Adamov criticized the closing of the Chernobyl plant in 2000, insisting it was safe. In 2002, the US government investigated the relationship between Adamov’s Pittsburgh-based consulting firm and a company that buys bomb-grade uranium taken from old Russian warheads, and after reprocessing, sells it to American nuclear power plants. (19) According to a story in the Moscow News at the end of Dec. 2005, Switzerland detained Adamov, but he was released to Moscow where he is placed in a pre-trial detention center while the Russian authorities investigate his activities. (20)

**USAID Projects**

American assistance to the populations victimized by the Chernobyl accident has often been funneled through the US Agency for International Development (USAID). These programs have primarily focused on health and on environmental interventions designed to reduce the level of radioactive contamination. Among these projects, a 3-year, $4 million Chernobyl Childhood Illness Program was launched in June 1998 to “screen and treat childhood mental and physical illnesses related to Chernobyl radiation” in the four most contaminated areas of northern Ukraine. Employing high-quality screening techniques and equipment, more than 70,000 children were examined. The investigation found that 8 percent of this large sample had thyroid abnormalities. A large number of the children were also at risk of severe depression. (Clifton’s chapter in this book provides a good deal of additional information about the impact of radioactive fallout on the development of cancers and other biological disorders.) More relevant for us here, this program provided technical assistance and training that has helped approximately 1000 service providers improve the management and care of thyroid cancer and psychosocial trauma cases.

Yet another USAID-supported activity extended the World Health Organization’s International Thyroid Project to Belarus, Moldavia, and Ukraine. Consistent with other USAID intensive training programs in genetic disease and diagnosis, screening and surveillance projects have also been established in all three Chernobyl-afflicted countries, leading to the formation of an alliance for birth defects prevention. Additional training and public information programs now stress breast cancer care, information and advocacy programs of effective, democratically-oriented communities in these areas. (21, 22, 23)

One of this organization’s projects, under a $1 million grant to the UN Office for Coordination of Humanitarian Affairs, funded two new community centers that are part of the network of
centers currently receiving support from FOCCUS. USAID also paid for the recruitment and training of social workers and psychologists and equipment for these new centers (24) (see Garnets’ chapter). Other USAID programs fostered a number of entrepreneurial-development projects in Slavutich, Ukraine, some of which sought to facilitate citizen participation in planning for community development, including one that is related to ecotourism. One result is that tourism to the “dead zone” and the Chernobyl nuclear power plant has increased greatly in the past few years.

Foreign assistance programs have traditionally been administered by both USAID and the US State Department. Recently the Bush administration announced that US foreign assistance is now clearly identified as “an essential component of our policy of ‘transformational diplomacy’.” Foreign aid must now be used “to promote responsible sovereignty, not permanent dependency.” Support to Chernobyl-affected countries will be guided by these new concepts. (25)

United Nations Programs

The United Nations has long been expected to provide emergency assistance, disaster management, and humanitarian aid following a widespread catastrophe in economically depressed developing nations. This has also been the case in the aftermath of the Chernobyl accident where the UN has carried the main burden in helping the victims of this horrific event.26 (26) The Soviet government initially refused emergency aid and held to this stubborn policy until the collapse of the USSR. When post-Soviet authorities called for help in 1992, UN agencies were the first to respond. Then, sometime later, the UN Interagency Program of International Assistance to Areas Affected by Chernobyl was formed. The Program’s assistance, unfortunately, fell well short of the need. A donor drive for US$9.51 million was initiated in 1999, but the world’s response was a mere US$677,000. And, as in many other instances, “donor nations” have not always lived up to their commitments.

The first UN agencies allowed into the afflicted areas to make initial assessments of the afflicted population’s needs were the International Atomic Energy Agency (IAEA), the Office of the Commissioner of Humanitarian Affairs (OCHA), and the World Health Organization (WHO), as well as the United Nations Education, Scientific and Cultural Organization (UNESCO). It was UNESCO that planned and initially financed the community centers that are discussed in Garnets’ and the current chapters.

Following these assessments, the UN distributed the appropriate responsibilities to the UN Office of Emergency Services, IAEA, and WHO. Later, OCHA became the lead UN agency. In 1999 the UN appointed a UN Chernobyl Coordinator.(26) In 2004, the UN Development
Agency (UNDP) was put in overall charge of the UN Chernobyl programs, but other UN agencies undertook a variety of Chernobyl-related activities.

Among the more significant of these, UNICEF launched a program (their Regional Network for Children in Central and Eastern Europe, the CIS, and the Baltic States) based on principles established by the 1989 Convention of the Rights of Children. This campaign is important for Chernobyl children in that it calls attention to vast numbers of youngsters who are living in Soviet-style institutions having no after-care support services and who are at risk for human trafficking, unemployment, and descent into street life, drugs and crime. Regions being served by this program also have the fastest growing rates of HIV infection in the world. The children in Chernobyl-affected regions are at greatest risk of developing these ailments because of the fragility of their immune systems, the stresses under which they live, and the lack of economic opportunities in their communities.

In Ukraine, UNICEF’s young people’s programs help promote the youngsters’ health and involvement in worthwhile community activities by focusing special attention on developing their “life skills” in schools. In addition, in iodine-deficient countries such as Belarus, Russia, and Ukraine, a special effort is designed to increase public understanding of the risks of iodine deficiency; among other things, and the need for iodized salt in diets deficient in iodine is emphasized.

Modern thought about disaster relief recognizes that successful recovery from catastrophic events typically progresses through a sequence of phases: first, immediate disaster relief, then a humanitarian phase, followed by a stabilization phase, and a development phase. The development phase refers to the time when the affected people have to mobilize themselves to rebuild their lives and their societies. They now have to relinquish their “victim” status and assert their own dignity and ability to cope with the catastrophe’s aftermath. If this development does not occur, the earlier relief and humanitarian aid do not bring the desired, long-term results.

This development phase of the recovery process is exactly what is needed in the Chernobyl-affected states at this time--nearly 20 years after the disaster. UNDP is currently responsible for Chernobyl matters. It has been given the mission “to help countries in their efforts to achieve sustainable human development by assisting them to build their capacity to design and carry out development programs.” At “the request of governments and in support of its areas of focus,” this agency is also charged with assisting “building capacity for good governance, public participation, and private and public sector development and growth with equity.” The UN recently announced the appointment of Kemal Dervis, a member of the World Bank for 22 years and a former finance minister of Turkey, to head the UNDP.
Nongovernmental Humanitarian Assistance

In 1989, at least partly out of frustration at the perceived inadequacy of their nations’ official assistance programs, many of the liquidators and firefighters who were the most severely affected by the disaster, formed a grassroots organization to challenge the shortcomings of their governments’ responses to the accident. This organization, the Chernobyl Union International, was intended to give the liquidators/firefighters a power base “from which to establish a support system, provide a measure of control over their destiny, and establish hope for a future for their families.” In 1989 they also launched a campaign to both inform the public at large what had actually happened at Chernobyl and to obtain greater, and more adequate, benefits. Since activities such as these were illegal before the demise of the Soviet Union, they carried great risk. In this sense, Chernobyl gave rise to the first grassroots politicians within the Soviet system. (30) (Also see Tykhyy’s chapter for a more detailed discussion of this development). But also important, the Chernobyl Union International has, since its inception, brought upwards of 50 million dollars in medical assistance to victims living all over the former Soviet republics.

Chernobyl-related grassroots activity continues today. Hundreds of victims marched in the Ukrainian capital during the weekend of April 25, 2005 to demand greater compensation from their newly-elected government. Current average monthly compensation rarely exceeds the equivalent of $50 per month and is paid irregularly. In St. Petersburg, Russia, a recent hunger strike by Chernobyl firefighters, and a court suit filed in The Hague, resulted in their winning claims against the government of Russia for unpaid pensions. (30, 31)

Help From Non-Afflicted Nations

People outside of the former Soviet block have also come to the aid of the victims of the nuclear catastrophe in Belarus, Russia, and Ukraine. Japan, undoubtedly sensitized by its own experience with the atomic bombing of Hiroshima and Nagasaki, has sponsored a considerable amount of research, as well as humanitarian assistance programs. But even persons in countries that have never been afflicted by a horrific nuclear explosion have helped ameliorate the accident’s dire consequences. Notably, Ireland has been the largest single contributor to humanitarian aid for Chernobyl victims, especially those in Belarus. (32) Some 100 separate groups in Canada and western Europe are also active. (33)
US Voluntary Activities

By the mid-1990s, after the fall of the Soviet Union, it became possible for the American public to provide assistance to those affected by the disaster. Volunteer and humanitarian efforts spread across the country, with special efforts focusing on medical, preventive and rehabilitative programs for children, and supplying the bulk of the US’s humanitarian aid to Chernobyl areas. CitiHope International was among the first of these agencies to respond. (34)

In the case of governmental assistance, the framework for formal United States foreign aid comes from the Freedom Support Act passed in 1992. Under this act, according to the US Department of State, over $52 million worth of donated supplies, primarily medical in nature, have been transported to the affected areas at a cost to the American taxpayer estimated to be approximately half a million dollars. Supplies were obtained largely through efforts of the New Jersey-based voluntary organization “Children of Chernobyl Relief Fund.” (35) Another large shipment is being prepared for distribution to mark the 20th anniversary of Chernobyl in April 2006.

Many American volunteer groups continue to provide assistance to people in the Chernobyl-contaminated areas. Three organizations are examples. All three began life in the mid-1990s as tax and import laws and technological communications (especially the Internet) made it possible for US organizations to operate in the affected countries.

Chernobyl Children’s Project USA.

Chernobyl Children’s Project USA, Inc., headquartered in Boston, Massachusetts, was founded in 1997 as a non-profit, tax-exempt, voluntary organization to provide respite visits, medical evaluations, and treatment to children whose health was adversely affected by the Chernobyl accident. This group’s annual report for 2004 indicates that to date over 1000 children have received rest and recuperation visits. In addition, one hundred twelve children have had surgical procedures valued at approximately $2.8 million. Local health professionals donated services worth over half a million dollars. This project also collaborated with 18 Massachusetts and New Hampshire towns, as well as local hospitals and physicians, at a cost of approximately a hundred thousand dollars. (36)

Chernobyl Children’s Project USA has become a model for similar programs in other parts of the world, notably Ireland, Sweden, England, and Japan. Twenty-eight states now have programs based on principles developed by this project. Besides working with the children, the
project translated many relevant materials for use in the Chernobyl region—from scientific medical journals to children’s books. Books were concerned with medical conditions, psychosocial adjustment to trauma, and the cultural differences that youngsters experience as they travel between their home country and the U.S.A. This is particularly important as children prepare to spend a month away from home and family in a healthier, yet decidedly foreign, environment.

This project reports a dramatic increase in the number of particularly demanding medical cases—especially cancer, cardiac, and orthopedic conditions—requiring expensive care and treatment. In spite of collaborative efforts with leading hospitals and medical groups in the area, the project’s volunteers, who also host and plan these visits, must increasingly raise the necessary funds. These costs have been covered by the Tyco Corporation ($600,000 for four years) but this grant recently ended and the future of this program is uncertain.

**Children of Chernobyl US Alliance (CofCUSA).**

Another national organization serving children from the contaminated areas is Children of Chernobyl US Alliance (CofCUSA). CofCUSA traces its beginning to Petaluma, California, in 1991, when a volunteer family provided a six weeks-long “respite” visit for ten children coming from Belarus. Taking up and expanding upon this function, CofCUSA is a federally tax-exempt organization and its mission is “to provide care, compassion, relief, and hope to those in the Chernobyl region, especially the children.”

Currently over 70 local groups, many of them faith-based or peace-and-friendship groups, are separately incorporated, and host Belarusian children each summer. Although CofCUSA has no paid staff, it serves as an important communication link between all related respite groups, develops program materials, offers organizational assistance to new groups, and provides debate and resolution regarding relevant policy matters. It also has established a credible network of relationships with other groups working with Chernobyl children, and shares much vital information through a list-serve and at an annual conference. (37)

Children participating in these visits are freed from the anxiety of radiation exposure, enjoy the doting of host families, eat clean and healthy food, and tolerate medical/dental examinations that assist personnel back home to properly monitor and improve their health. It has been shown that, for a short time, children actually lose some of the radioactivity accumulated in their body. (38)

While complete data are not available for all of the years CofCUSA has been in existence, it is estimated almost 22,800 children have been hosted by the various groups under its general
umbrella. The estimated cost per child is $5000, including *pro bono* dental/medical services and humanitarian aid provided by host parents. Thus, this project has provided benefits worth over $1.1 million dollars. (39)

CofCUSA also sponsors a humanitarian aid program that provides dental supplies, vitamins, over-the-counter medicines, first-aid kits, clothes, and educational materials to children and families in the Belarus-Chernobyl region. Some programs have direct connections with orphanages, hospitals, and clinics to which they send supplies.

The number of Americans working on such projects is in the thousands. These people raise funds for visas and air transportation and experience the youngsters’ excitement when they arrive. Although these programs typically cover the expenses of any child only once, many families pay for their young guests to return again and again and a few families now provide funds for their Belarusian youngster to enroll in university education in Belarus. For these families, Chernobyl is not *long ago and far away.*

Some people familiar with these programs question whether the programs might negatively effect children’s satisfaction with life in their own countries. The Belarusian government appears to be particularly concerned about this problem. In December 2004, CofCUSA’s local programs and similar programs in the United Kingdom, were shaken by Belarus’ President Alexander Lukeschenko’s comments that children return from these visits “washed by a consumerist society.” Although he subsequently threatened to cancel all such visits, Belarusian youngsters were brought to the US as before in the summer of 2005. However, American adoptions of Belarusian children have been stopped. (40)

In the year 2000 there were almost 500,000 people in Belarus who were eligible for these respite visits or to compensation if they did not receive this benefit. However, only 293,895 were offered this benefit. In Ukraine, 372,900 citizens received such visits in 2000. This is a tremendous drain on economy of these countries. A recent UN report on consequences of Chernobyl recommended that international organizations providing these programs “rethink” their efforts by redefining the title and purpose of these programs (e.g., cultural focus instead of health) or redirecting their organization’s financial resources to improving primary health care for children in the affected areas. (41)

_Friends of Chernobyl Centers US (FOCCUS)_

Friends of Chernobyl Centers U.S. Inc. (FOCCUS) also emerged in the mid-1990s. Although years had passed since the Chernobyl disaster, it was not until the break up of the Soviet Union...
that the American public became fully aware of the magnitude of the accident’s effects and developed ways to help the victims. (42)

FOCCUS was created specifically to support the network of Community Centers established by UNESCO in 1994 and described by Garnets in her chapter. It is the only organization in the world dedicated solely to supporting these pioneering centers and their programs.

The Centers came to the attention of Americans attending an international conference of human service professionals in Russia in 1994 and Ukraine in 1995. This small group subsequently launched a project to support the Centers and by 2002, FOCCUS became a non-governmental, tax-exempt, totally volunteer organization.

It quickly became clear that the Centers had to deal not only with the impact of the world’s greatest nuclear disaster, but also to deal with it in the context of the disintegration of social, economic, and political institutions that had been in place during 75 years of Soviet rule.

As Garnets points out, the Centers had no model for the mission they were undertaking. Existing pre-school and “community centers” and volunteer groups functioning within the context of the Communist party were not designed to be responsive to consumer and community concerns. Besides, the Communist government had deliberately lied to the public about the Chernobyl disaster and its potential consequences. The first task of the Centers was to get people to believe that they were hearing the truth from the Centers’ staff. Staff members overcame this distrust by relating to people in a manner very different from the Soviet style: they encouraged questions, discussion, and debate, and also acknowledged people’s right to ask questions and to expect truthful answers, etc.

These Centers were first established as crisis intervention and information centers. They are now clearly functioning to foster the “development phase” of recovery from disaster. This phase insures that previous disaster and humanitarian aid efforts are used effectively. It also is essential if affected populations and communities are to move beyond their feelings of “victimization” and hopelessness. (43)

This phase demands coordination and cooperation at all levels of government--local, regional, national, and international. The Centers now have collaborative relationships with schools, hospitals, orphanages, local government, and the increasing number of non-governmental organizations in their community. For example, in 2005, the five Ukrainian Centers provided services to 73,407 participants in a variety of individual, group, and community meetings. They published information booklets on subjects such as food preparation, breast cancer, iodine deficiency, alcohol and drug abuse, and HIV, as well as changes in Chernobyl-related legislation that would affect local populations. (44)
These Ukrainian Centers’ activities are financed through their participation in selected UN projects, local government sociological survey work, and $40,000 from the national government. Given Ukraine’s current economic situation, it is unclear if this support will continue in the country’s 2006 budget proposals. If that happens, the decade of outstanding and pioneering post-disaster work of these Centers will be lost to the world. FOCCUS is searching for ways to prevent, or to compensate for, this potential loss of support. The strategy will involve US government bodies and officials, cooperation with the Ukrainian Embassy in Washington, and identification of other groups that might be an effective voice on behalf of the Centers.

The FOCCUS program attempts to meet needs identified by the Community Centers established in Belarus and Russia, as well as in Ukraine. It provides support that will make program efforts more effective. For example, FOCCUS funds have purchased vans, video and computer equipment; constructed a new community meeting and seminar room; remodeled a kitchen; and supports weekend coverage for a telephone crisis “help” line. In 2005, four centers each received a grant of $5000 to fund programs on (a) reproductive health; (b) educating young children about effects of radiation; (c) training high school volunteers so a summer camp program can be run for young children; and (d) teaching personal safety behaviors to school children.

Staff training has been a major aspect of the work of FOCCUS. Early sessions focused on professional development: ethical behavior, models of helping process and interventions, and models of programs that could be adopted by the Centers. A series of sessions were held on social democracy. In 2006, FOCCUS will fund another three-day training institute in Kyiv for about 45 staff members. Content will deal with areas requested by staff and strategic planning strategies that will maximize coordination of FOCCUS activities in light of the Centers’ identified needs.

FOCCUS is also a collaborative organization. This philosophy enables FOCCUS to magnify its efforts. There are many examples of how collaboration with the Children of Chernobyl Project USA and the CofCUSA groups benefit the Centers. Collaboration with the University of Wisconsin-Madison is expanding with connections to educational, health and international programs.

FOCCUS also has a critical goal of educating the public about the Chernobyl disaster and its aftereffects. On a recent study tour, twenty-one people from three countries spent two weeks visiting the five Ukrainian centers, touring the Chernobyl nuclear power plant and the “dead zone,” and meeting with community officials and families. This has stimulated efforts nationwide to tell the story of Chernobyl to a wider public through university and high school science classrooms. A new FOCCUS project supporting teachers who want to teach about Chernobyl is being launched this year. A national conference on Chernobyl, in cooperation with the Univer-
University of Wisconsin, is scheduled for March 2006 to commemorate the 20th anniversary of the disaster.

Funds to support FOCCUS activities come from local fundraising events and from individual donors from across the country. Since its first fund drive in 1997, FOCCUS has provided over $100,000 in funds and services to these centers, plus thousands of dollars in *pro bono* travel, consultation, and teaching services. Ten Center staff members have had study tours to the United States.

*Foreign Aid, International Relations and Chernobyl*

US foreign aid has actually grown over past few years, but at the current level of .16 percent of gross national income, the United States are next to last on the list of the world’s “rich” countries who donate to UN aid projects. Only Italy is lower, at .15 percent. Norway is highest at 0.87. (45)

Belarus currently receives little if any formal US foreign aid. Aid to Ukraine dwindled as the corruption of President Kuchma’s tenure became apparent. The recent success of the Orange Revolution may see an increase in American foreign aid flowing to Ukraine.

There is no doubt that the political scene in Belarus, Ukraine, and Russia will continue to affect both volunteer and formal government relations that impact on people whose lives have been so severely disrupted by the Chernobyl disaster.

**BELARUS**

Belarus, a country whose population is 10 million, is the territory most affected by the Chernobyl disaster. It is estimated that over 70 percent of the country is contaminated. The economic consequences of the disaster for Belarus are estimated to be US$300 billion over time. (46) Between 1991 and 2003, total spending on Chernobyl was more than US$13 billion. While the economy of the country is growing, the percent of the national budget for Chernobyl expenses has dropped from 19.9 percent in 1992 to 5.3 percent in 2001, and 1.6 percent in 2002. (47) The needs of the Chernobyl population have not declined during this period, but it appears that the government has decided that if the country is to survive, available monies must focus on national economic development. Much of the international humanitarian and foreign aid going to Belarus since the Chernobyl disaster has gone into improving health care of the entire population. The World Health Organization now ranks the Belarus health care system as 53rd of 190 countries.
Belarus relations continue to be an issue for the United States. Some Belarusian diplomats have been refused permission to visit the US. Lukashenko continues to be angry about the US State Department’s report on religious freedom in Belarus, passage of the US Belarus Democracy Act, and travel restrictions placed on Belarusian government officials implicated in election fraud and human rights abuses. (48)

On a more positive note, Belarus recently announced establishment of an ambitious program of international Chernobyl cooperation. (49) The main objective of this initiative is to attract various types of foreign assistance to deal with Chernobyl problems. This proposal will require systematic work regarding objective assessment of radiation, ecological and socio-economic situations in the affected regions. The release announcing this initiative indicates that continuous efforts are being made to inform the international community about what the state is doing to mitigate negative consequences of the disaster and about unresolved problems of contaminated territories.

Belarus, in cooperation with the UN, has also announced an international conference to commemorate the 20th anniversary of Chernobyl in April 2006.

In spite of such positive developments, the government of Belarus encourages citizens to continue to live on contaminated land and to farm land that has been designated as contaminated.

President Lukashenko is also actively recruiting people to re-populate land that has been designated as contaminated but is now designated as “clean.” These new settlers come from Bosnia, Serbia, Herzegovina and, most recently, from Chechnya. (50)

Belarus is counting on an additional World Bank investment of about US$50 million beginning in 2006 to help deal with Chernobyl problems. These funds would be spent on improving the power and water supply to contaminated regions, rehabilitating forest areas, and reviving agro-industrial production. With these new utilities, re-settlement of regions despite previously high levels of radioactive contamination, especially cesium 137, will undoubtedly expand. Many re-settled people long for an excuse to return home, even to contaminated land, and many more from war-torn and economically-depressed sections of the former Soviet Union may be tempted with visions of a peaceful existence and the promise of a home. (51, 52)

The economic drain of Chernobyl for this small country, the most heavily contaminated of the three countries, indicates that over 500bln BYR (at the time of this writing, 2152 rubles per US dollar) will be spent to mitigate the Chernobyl consequences between 2006 and 2010.
UKRAINE

Immediately on achieving independence from the Soviet Union, Ukraine used the devastating impact of the Chernobyl disaster to attract huge sums of international aid. They partially justified this by indicating the vast number of victims on the national registry for Chernobyl. Unfortunately this registry was established prior to establishment of strict registration procedures and eligibility requirements. As in Belarus and Russia, huge numbers of people were registered without proper documentation of their exposure or injury. Now these numbers are a threat to Ukrainian economic progress but efforts to cull people from the registry are met with anger and resistance. It is reported a large proportion of the 600,000 to 800,000 firefighters in the months immediately following the disaster were Ukrainian. (53)

In the year 2000, it was estimated that five percent of the Ukrainian national budget was needed to meet priorities directed to alleviating Chernobyl consequences. In 2001, the Ukrainian budget for Chernobyl-related activities was US$332.75 million. However, given the severe economic conditions in the country, this was not realized. Currently five to seven percent of government spending each year is devoted to Chernobyl-related benefits and programs. (54)

Current figures report 2.32 million Ukrainians have been affected by the disaster, including 352,000 children. Up to 4600 people are still waiting for resettlement from heavily contaminated areas and 400 to 600 people (mostly elderly pensioners) were living inside the highly-contaminated exclusion zone. In August 2003, the Ukrainian Parliament considered permitting up to 1500 families to return to live in the exclusion zone. If people do return, they will face not only constant exposure to low-level radiation whose health effects are unknown, but also the threat of disastrous new contamination should the deteriorating and dangerous site of the Chernobyl nuclear power plant site experience another accident.

The Ukrainian debate and the Belarusian decision to declare previously designated contaminated areas now safe for habitation is in line with the UN Chernobyl Forum report’s statement: “Where in the light of the best scientific knowledge it is reasonably possible, measures should be adopted to integrate less severely affected areas back into productive use as soon as is practicable.” However, what constitutes “best scientific knowledge” is not addressed nor are the scientific, political, and economic rationales for this determination explored.
RUSSIA

Russia reportedly has 508,000 people on the Russian State Medical and Radiation Registry. Of these, 168,000 are liquidators. In 1999, less than two percent of the funds needed were allocated from the national budget. Russian expenditures for Chernobyl relief activities have been integrated into the national budget expenditures for Chernobyl so are not as visible as those in Ukraine and Belarus. Specific Chernobyl relief activities have focused on housing for liquidators and increasing vitamin-enriched foodstuff production.

Social commentator David Brooks has pointed out the disastrous state of the Russian health care system. (55) The general population is dying younger, violent deaths are high for men. There is a reported “explosion of heart attacks and strokes due to heavy smoking, increased alcohol consumption, an explosion of HIV-Aids. The population is declining rapidly. For every 100 births, there are 160 deaths.”

Within these general trends, those affected by radiation exposure, those living on contaminated land, those who struggled through the stress of resettlement, those who participated in the clean up, those whose immune systems have already been compromised, are at extremely high risk for health problems.

Economic reform legislation recently proposed cuts in Chernobyl-related benefits. In a village 300 miles south of Moscow, a group of Chernobyl victims recently launched a hunger strike, saying proposed reforms stripped them of vital benefits. Previous hunger strikes were staged in St. Petersburg.

In 1994, a joint Russian/US Coordinating Committee for Radiation Effects Research was formed to coordinate research on health effects of exposure to radiation in the Russian Federation. The project was renewed through 2005. The goal of this research is to minimize consequences of radioactive contamination on health. Related environmental studies examine public health risks from radiation exposure to workers involved in nuclear weapons production in the former Soviet Union. One study looks specifically at the relationship between health effects and chronic, low-to-medium-dose radiation exposure. As of December 31, 2003, ninety scientific articles had been published in peer-reviewed journals and the science is recognized worldwide for its critical contribution to radiation research. (56)

Another Russian/American Department of Energy Program is a radiobiology human tissue repository at the South Urals Biophysics Institute. Here, tissue samples from individuals accidentally exposed to different types of radiation are stored for study.
The economies of all three of these affected countries have improved since the Chernobyl disaster, but NOT in the affected areas. People living in contaminated areas are being left out of economic recovery and development efforts.

**Health Research Issues**

There are now over 400 nuclear energy reactors in operation around the world. Issues regarding nuclear safety, plant design, and regulations regarding disposal of nuclear waste, the relationship of nuclear energy expansion to the development of nuclear warheads and weapons of mass destruction, are the focal point for many international research issues and debates. Issues of “risk analysis” and health consequences of potential accidents are often at the heart of these debates.

This brief section indicates only a few of the issues relating to the complex and controversial issues regarding Chernobyl, radiation exposure, and health effects. Readers are referred to the recently released Chernobyl Forum Report and to the International Committee on Research and Information Network (ICRIN, [www.chernobyl.info](http://www.chernobyl.info)) for more complete examination of these issues.

Perhaps the most controversial and least settled issues arising from the Chernobyl accident are those of the long-term health impact on the millions who were exposed. (57) Much excellent research has been done. There are valid questions and issues, however, underlying the results and the interpretations of these results. Researchers often debate each other.

Research studies on the long-term health effects of the Chernobyl disaster face particular problems. For epidemiologists, the lack of reliable data and registries kept by the Soviet Union means there are no reliable baselines on which to establish comparisons, for example on the rates of infant mortality or birth defects prior to Chernobyl. In addition, the lack of specific “dose rates” for any individual or group of individuals presents a problem. (See Clifton’s chapter)

There are 150,000 to 200,000 people permanently residing in areas designated as “highly contaminated” and eating contaminated food every day. This is the first time in history that massive populations have been continuously exposed to this type of low-level radiation.

The impact of continuous exposure to this low level of radiation on human health is one of intense debate. Besides the health effects of direct exposure following the accident, how does this low-level, continuous exposure affect well-being? For example, cesium$^{137}$ released during the disaster entered the soil where it will stay for hundreds of years. It then enters the body through consumption of dairy and other animal products. Once ingested, cesium$^{137}$ plays havoc

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with internal organs. How does this exposure influence health stature? Since children are major consumers of dairy products, how are their developing bodies and systems being affected?

Questions regarding the impact of radiation on the DNA have been the subject of research for years without finding answers to the question of how much radiation will subject cells to breaking; or if this breaking occurs, is it passed on the next generation as harmful mutations. The effects of this “breaking” may not be known for up to several decades (58), but the International Chernobyl Radiological Center, partially funded by the US, is investigating this question by doing research on small mammals in heavily-contaminated zones.

The interaction between radiation exposure and stress lies at the core of another heated debate centering on the cause of rapidly rising heart, lung, blood, and respiratory conditions in the Chernobyl-affected populations. It has been postulated that severe stress reactions due to suspected radiation exposure, the stress of evacuation, facing the uncertainty of future health problems for themselves and/or their children, are contributing to this rise. The two major UN reports on effects of Chernobyl consider stress response, which in turns influences health status, is the major consequence of the Chernobyl disaster. There are, however, many who question this position. (See Speckhard’s and Moore’s chapters.)

The stress of poverty and unemployment and the lack of access to medical care in some areas are major factors contributing to the increasing health problems experienced by thousands of those exposed by Chernobyl’s disaster. The poor condition of the infrastructure in some affected communities, e.g., water, electricity, waste disposal, also adds to the already fragile health of populations. Also, the medical system in all three affected countries declined following the disaster because of national economic problems that are still unresolved. Many of these economic conditions also affect populations not exposed to Chernobyl radiation, however, so the efforts to blame Chernobyl as the “cause” of these effects are unreliable.

Although many respectable international bodies and researchers undertake bona fide research projects, there has not been a formal body to provide oversight, peer review, and post-hoc evaluations of studies published. Those searching for answers to particular questions regarding the health impact of Chernobyl will find conflicting findings but no way to ascertain which findings are scientifically sound. Unfortunately, this results in a public that has developed suspicion and confusion about many research findings. They therefore often attribute results that deviate from their own personal opinions to the researchers’ bias or vested interests. This is particularly true of research studies done by the International Atomic Energy Agency, the US Department of Energy, and even the World Health Organization—organizations with the funds and legitimacy to conduct such research but often perceived as having vested interests.
Another complicating factor is that much of the published longitudinal research findings on radiation are drawn from joint international studies focused on World War II atomic bombings and extrapolations from these studies to Chernobyl are sometimes questioned. (See Clifton’s chapter.) The Japanese are currently concentrating their expertise to yield more fruitful data on low-dose radiation effects on human health. (59)

Cognizant of these problems, the UN has taken two important steps. In 2002, the UN established the Chernobyl Forum. In announcing these developments, the UN Coordinator of International Cooperation on Chernobyl stated: “Quality information on the consequences…that is reliable and freely available…is essential if we are to turn Chernobyl from increasingly a ‘forgotten tragedy’ into a well-understood and broadly supported example of international cooperation.” In cooperation with the Swiss Agency for Development and Cooperation, a major comprehensive web site on up-dated activities and information regarding the Chernobyl disaster was launched at www.chernobyl.info.

In June 2003, the International Chernobyl Research and Information Network (ICRIN) was launched. (60) This is an international collaborative mechanism between leading international research institutions and national research institutions. This network has a broad base of professions that will focus on interdisciplinary perspectives on research issues. The goals of ICRIN include (a) recognizing excellent and creditable research already done; (b) providing a synergistic approach to analysis of existing findings that will point the way to new research that may be needed; (c) ensure effective dissemination of research findings; and (d) bring national research institutions in the affected countries into the mainstream of international scientific research.

Conclusion

This chapter stressed the voluntary and collaborative and bureaucratic linkages between governments and groups that are working to alleviate the pain and suffering of those living in the aftermath of Chernobyl. It is necessary to know of these relationships if we are to learn from the current situation facing the people and the territory in Chernobyl-affected areas.

It also seeks to strengthen the perspective that “out of sight, out of mind” and “long ago and far away” is not a true conception of the continuing and active American involvement in the Chernobyl disaster. While it is certainly true that more needs to be done, it is evident that the United States has NOT disengaged from the effects of this disaster. Many official links exist between US government agencies and other international organizations with a vested interest in

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learning as much as they can about the effects of the Chernobyl disaster. The voluntary sector of the US is alive and well as it continues to help mitigate the problems of post-Chernobyl populations and communities.

The scientific and political debates on the links between radiation exposure and health, on the dangers of nuclear proliferation, and on environmental issues pertinent to nuclear power development continue. In the meantime, a frustrated public searches for “answers” and relief from the anxiety generated by the Chernobyl disaster and the accident at Three Mile Island. The public is frustrated by the lack of certainty about health effects of radiation and the equivocal answers from reputable scientists. This situation is further aggravated by the media which publicizes inadequate or inaccurately presented research findings or feel no need to publish developments about Chernobyl because it happened “so long ago and far away.”

Chernobyl is forever tied to nuclear energy. For nearly 20 years, the ghost of Chernobyl has influenced nuclear energy debate in this country and has succeeded in forestalling the expansion of nuclear power plants. Jesus E. Gomez has pointed out that Chernobyl’s accident “was a turning point for the nuclear power industry worldwide.” (61) Now, aging plants in the United States are reaching the end of their licensing period and must be revamped or closed and decisions must be made about their future. The issues of how to dispose of the waste from nuclear energy plants and nuclear weapons that has accrued for over two decades are far from resolved.

In recent years, the issue of global warming has garnered support for the expansion of nuclear energy since nuclear power would supposedly displace the contaminating effects of energy produced by coal and gas. The question being posed is “What price is the world willing to pay to stop this global warming process?” Sir Dillwyn Williams at the University of Cambridge, England, recently argued that: “If societies want to continue using nuclear power, the benefits must be balanced against the risks.” A modern concept of “risk assessment” poses the question: how much risk is the world (and the individual countries in it) willing to assume in order to maintain or enhance a current lifestyle heavily dependent on oil, coal, and gas? What alternatives exist? Who and how will it be decided how much “at risk” any individual life, or the collective lives of others around the globe, will be? Will the answer to this “risk analysis” be based on political and economical considerations, or on self-interest and exploitation, or on social justice?

To explore these issues, efforts to become a scientifically literate nation must be expanded. New opportunities must be created so everyone may increase their knowledge about the nuclear age we live in and may better understand the nature of science. Science deals with probability
and risk, concepts that do not come naturally to many people. The juxtaposition of “math” and “medicine,” which is required to evaluate the health effects of radiation, stress, and other related Chernobyl issues leaves an interested public quite bewildered and confused. Education in the public schools and universities, both in science and the humanities, must foster interdisciplinary perspectives on what is involved.

Those of us committed to the people of Chernobyl, those of us who are studying Chernobyl, have a responsibility to tell others what has been learned. Many people are listening to the voices of Chernobyl. Many hearts are connected to those whose lives have been devastated by Chernobyl. Many realize that Chernobyl is with us here, today, and is not by any means long ago and far away.

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