Chernobyl: The Event and its Aftermath

Edited by

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Published in collaboration with Goblin Fern Press, ISBN 1-58589-048-2

This e-book has been published on behalf of
FOCCUS, Friends of Chernobyl Centers, United States, www.foccus.org

by:
Goblin Fern Press, Madison, Wisconsin
www.goblinfernpress.com
Toll-free: 888-670-BOOK (2665)

E-book: ISBN: 1-59598-048-2 CD: ISBN: 1-59598-049-0

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THE ACCIDENTS AT THREE MILE ISLAND AND CHERNOBYL(1)

Colleen F. Moore

Colleen Moore, Professor of Psychology at the University of Wisconsin, Madison, specializes in the study of children's psychological development. Her 2003 book, Silent Scourge: Children, Pollution, and Why Scientists Disagree focuses on the impact of pollutants on children's intellectual functioning, behavior, and emotional states.

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 seige. (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 respresentativeness 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 accident.

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 there had been held (Freeman, 1981). Almost all nuclear power plants were controversial in some way during this time, and the public was becoming more skeptical of nuclear power safety even before the accident (Hohenemser et al., 1977; Ahearne, 1987).

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.

What people think and do about threatening situations can affect the amount of stress those situations create (see Kleinke, 1991 for a readable overview). There are three major variables: threat appraisal and risk perception, coping strategies, and perceptions of control, cause, and blame (see Lazarus & Folkman, 1984 for an influential theoretical approach to stress and coping). These three aspects of stress and coping are intimately related to each other, to the severity of the event, and the severity of the impact of the event on a person. In Figure 1, I have outlined some of the variables involved in stress and coping. These kinds of variables were studied with the TMI area residents after the accident.

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 problem 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 interviews with Gofman and Sternglass in which they relate their personal experiences).

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 Chornobyl (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 microraions . . . 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 deposited 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.[5] **5** 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). The 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--∂-power and ß-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 ß-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 displayed 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 fall out (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 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 Chornobyl 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 Chornobyl 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 neurocognitive tests (McDiarmid et al., 2000). The dose-response relationship bolsters the interpretation that exposure to uranium may affect neurocognitive 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 Chernobyl 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 Chernobyl 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.