Consequences of the Nuclear Power Plant Accident at Chernobyl

HAROLD M. GINZBURG, MD, JD, MPH
ERIC REIS

Dr. Ginzburg is the Senior Medical Consultant, Office of Emergency Preparedness, Health Resources and Services Administration, Public Health Service. He was a member of two international health teams that were tasked with evaluating the medical and psychological consequences of the nuclear power plant accident at Chernobyl in the Soviet Union on April 26, 1986.

Mr. Reis is an undergraduate student at Harvard University.

Tearsheet requests to Dr. Ginzburg, Office of Emergency Preparedness, 7-34 Parklawn Building, 5600 Fishers Lane, Rockville, MD 20857.

Synopsis

The Chernobyl Nuclear Power Plant accident, in the Ukrainian Soviet Socialist Republic (SSR), on April 26, 1986, was the first major nuclear power plant accident that resulted in a large-scale fire and subsequent explosions, immediate and delayed deaths of plant operators and emergency service workers, and the radioactive contamination of a significant land area. The release of radioactive material, over a 10-day period, resulted in millions of Soviets, and other Europeans, being exposed to measurable levels of radioactive fallout.

Because of the effects of wind and rain, the radioactive nuclide fallout distribution patterns are not well defined, though they appear to be focused in three contiguous Soviet Republics: the Ukrainian SSR, the Byelorussian SSR, and the Russian Soviet Federated Socialist Republic. Further, because of the many radioactive nuclides (krypton, xenon, cesium, iodine, strontium, plutonium) released by the prolonged fires at Chernobyl, the long-term medical, psychological, social, and economic effects will require careful and prolonged study. Specifically, studies on the medical (leukemia, cancers, thyroid disease) and psychological (reactive depressions, post-traumatic stress disorders, family disorganization) consequences of continued low dose radiation exposure in the affected villages and towns need to be conducted so that a coherent, comprehensive, community-oriented plan may evolve that will not cause those already affected any additional harm and confusion.

ON APRIL 26, 1986, IN CHERNOBYL, Ukrainian Soviet Socialist Republic (SSR), an accident occurred at Reactor 4 of the Chernobyl Nuclear Power Plant (NPP). There was an initial explosion and fire in the core containment facility, a subsequent fire in the reactor's graphite moderators, and a 10-day long (April 26–May 6) release of gases and aerosols containing great amounts of radioactive material that resulted in the widespread dispersion of clouds of radioactive nuclides. Reactors 1 and 2, which are physically separate from the damaged reactor, were not immediately threatened; the nearby Reactor 3 was structurally endangered by the fires. The graphite-moderated, boiling-water-cooled design of the Chernobyl reactors contributed to both the start and the severity of the accident.

Soviet experts estimate that 50 MCi (million curies) of noble gases (predominantly xenon and some krypton) and a total of approximately 50 MCi of other radionuclides were released to the environment during the 10-day period. Approximately 20 MCi of nonnoble gas release occurred on the first day of the accident. It is the opinion of the U.S. Nuclear Regulatory Commission (NRC) that the Soviet estimates of all releases and release rates (except for the noble gases) have an uncertainty range of ± 50 percent (*1*). Table 1 presents the core inventories and total releases at the time of the Chernobyl nuclear power plant accident (*2*).

At present, approximately 250 deaths have been directly attributable to radiation exposure (*3*). The nature and extent of the current physical and psychological morbidity directly and indirectly attributable to the Chernobyl NPP accident are unknown; estimates of future morbidity and mortality are incomplete.

Extent of the Accident

Extent of radioactive release. Due to the nature of the nuclear power plant construction at Chernobyl, it is estimated that all radioactive noble gases contained in the reactor were released at the time of the initial event. As noted in table 1, approximately 98 percent of the noble gases appears to have been xenon (^{133}Xe, half-life of 5.27 days) (*1*). The Ukrainian area around Chernobyl is known to be an iodine-poor region, with endemic goiter common. Therefore, a larger than normally expected percent of radioactive iodine-131 was absorbed by the iodine-deficient population. It is expected that one of the long-term effects of such an exposure will be an increase in the level of thyroid disease in the population (*4*). Other radioactive nuclides like cesium (Cs) and strontium (Sr) have long half-lives and enter the food chain. Cesium has a ubiquitous distribution throughout all tissues; it is a potassium congener. Cesium, unlike strontium, which is a calcium congener, is not strongly retained in the body. Cesium has a half-life, in the body, of approximately 3 months (*5*).

Because of the prolonged evolution of the accident, the dispersion patterns for each of these and other radioactive nuclides are not congruent (*4*). Chemical forms of the released radionuclides were reported as being quite variable. Physical sizes of radioactive particles were in the range of less than 1 micrometer to tens of micrometers.

The immediate characteristics of the accident (*6*) can best be visually understood by examining the figure and noting that there were four stages of dispersement of radioactive material (*1*).

1. The first stage was the initial burst release on the first day, April 26, of the accident (day 0 on the figure). This release occurred without warning. The explosion caused a mechanical discharge of dispersed radioactive fuel. The released radionuclides, in this stage, were composed of fission products in the fuel. They were enriched with nuclides of volatile elements including iodine, tellurium, and cesium.

2. The second stage, days 1 to 5 from April 27 to May 1, 1986, was the period of decreased release; it was approximately one-sixth of the average release rate for the first day. During this time there was a continued aerial deposition of about 5,000 tons of a variety of materials including 40 tons of boron carbide, 800 tons of dolomite, 1,800 tons of clay and sand, and 2,400 tons of lead. (The large quantities of lead deposited on the reactor site, with some percent of it being vaporized and distributed in rain clouds, may possibly account for some of the currently reported children's medical problems.)

3. In the third stage, days 6 to 9 from May 2 to 5, there was a rapid increase in the release rate, reaching a daily value of about 70 percent of the first day's release. The Soviets believe that this release was from (*a*) the re-ignition of the fuel by residual decay heat and (*b*) the possible carbonization of uranium dioxide (UO_2), making it easier for fission products to escape.

4. The fourth and final stage, commencing on day 10 after the accident, May 6, 1986, was characterized by a sudden decrease in the release rate to about 1 percent of the initial rate. The Soviets believe that this decrease was due to their introduction of liquid nitrogen into the reactor vault and the formation of more refractory compounds of fission products secondary to the earlier prolonged aerial deposition of boron carbide, dolomite, clay, sand, and lead.

Table 1. Core inventories and total releases at the time of the Chernobyl accident, April 26, 1986

Element	*Half-life (days)*	*Inventory (MCi)*[1]	*Percentage released*
Kr-85	3,930	0.89	100
Xe-133.....	5.27	46	100
I-131.......	8.05	35	20
Te-132.....	3.25	8.6	15
Cs-134.....	750	5.1	10
Cs-137.....	1.1×10^4	7.8	13
Mo-99......	2.8	130	2.3
Zr-95	65.5	119	3.2
Ru-103.....	39.5	111	2.9
Ru-106.....	368	54	2.9
Ba-140.....	12.8	78	5.6
Ce-141.....	32.5	119	2.3
Ce-144.....	284	86	2.8
Sr-89	53	54	4.0
Sr-90	1.02×10^4	5.4	4.0
Np-239.....	2.35	3.4	3
Pu-238.....	3.15×10^4	0.027	3
Pu-239.....	8.9×10^6	0.023	3
Pu-240.....	2.4×10^6	0.032	3
Pu-241.....	4,800	4.6	3
Cm-242....	164	0.7	3

[1]Decay corrected to May 6, 1986, and calculated as prescribed by the Soviet experts.

NOTE: The Soviet estimates of all releases and release rates except for the noble gases have an uncertainty range of ± 50 percent. MCi = millicuries.

SOURCE: Reference 2, table II.

The radioactive cloud that formed at the time of the accident produced radioactive trails on the ground in both westerly and northerly directions. Radiation levels in the northerly direction (towards Byelorussia and ultimately towards Scandinavia), at distances from 5 to 10 kilometers (3 to 6 miles), and at an altitude of 200 meters (m) (approximately 655 feet), reached levels of 1,000 millirems per hour (mR per hr) on April 27 and 500 mR per hr on April 28. On April 27, at 1,200 m (approximately 3,940 feet) altitude and 30 km from Chernobyl, the radiation level was 1 mR per hr. On April 28, areas of Scandinavia and northeast Poland were affected. By May 2, the initial cloud had reached the United Kingdom. By May 5, the main plume of radioactive material was over southern Germany, Italy, Greece, and eastern Europe, and at the same time the initial plume was dispersing over the Atlantic Ocean (*1*).

Extent of radioactive contamination. The Soviet strategy, in the early 1980s, was to locate nuclear power plants 25 to 40 km (16 to 25 miles) from cities (*1*). The Soviets had planned a 3-km safety zone around each nuclear power plant and, once the nuclear power plant was built, they restricted the building of factories within a radius of 3 to 10 km. In contrast, the 30-km zone that was created after the Chernobyl accident was an "ad

Table 2. Criteria for making decisions for the protection of the population

Radiation or contamination and measurement units	*Level A*[1]	*Level B*[2]	*Protection measures*
External β −, γ radiation (radiation dose in rems)	25	75	Temporarily sheltering and limiting the time in an open space
Dose to thyroid resulted from radioactive iodine through inhalation (rems)	25	250	KI prophylaxis, temporarily sheltering, and evacuation (children)
Integrated specific activity in the air (MCi per liter):			
Children	3	20	
Adults	20	200	
Total consumption of I-131 with food (MCi)	0.8	8	Eliminating or limiting the consumption of contaminated food, relocating dairy cattle to uncontaminated pastures, KI prophylaxis
Maximum contamination of fresh milk or daily food ration (MCi per liter, MCi per day)	0.06	0.6	
Initial density of I-131 disposition on pastures (MCi per m^2)	0.4	4	

[1] If a dosage does not exceed this level, there is no need to perform urgent measures which will temporarily disrupt normal life of the population.
[2] If a dosage reaches or exceeds this level, urgent measures have to be taken, even if the measures will temporarily disrupt normal life of the population and economic development in a particular region.
NOTE: If a dosage exceeds Level A but does not reach Level B, decisions should be made in accordance with a concrete situation and local conditions.
SOURCE: Reference 7.

hoc'' measure resulting from the severity of the accident.

The Soviets had also established criteria to protect their citizens from exposure to excessive levels of radiation (table 2, reference 7). When the predetermined levels were reached, 135,000 people living within the 30-km zone were evacuated; 91,600 from the Ukrainian SSR, 24,700 from the Byelorussian SSR, and 18,100 from the Russian Soviet Federated Socialist Republic (SFSR). The largest city in the zone, Pripyat, with an estimated population of 45,000, was the home of many of the Chernobyl nuclear power plant workers (*8*). It is presently (and will be for the foreseeable future) a ghost town. It is located approximately 2 miles from the power plant. (As a point of reference, Kiev, a city of 3 million, is located approximately 120 km south of Chernobyl.)

Wide scale evacuation did not commence for 36 hours. Pripyat was evacuated only after the wind shifted. The residents left with what they could carry. There would be no returning for personal items or furniture. One significant reported difficulty was that the peasants in the surrounding villages refused to leave their animals. Therefore, a livestock evacuation also had to be initiated (*1*).

The Soviets have established three zones (*9*), based on the level of ^{137}Cs contamination:

1. Periodic control zone—^{137}Cs levels between 5 and 15 curies per square kilometer (Ci per sq km).
2. Permanent control zone—^{137}Cs levels between 15 and 40 Ci per sq km.
3. Closed zone—^{137}Cs levels in excess of 40 Ci per sq km.

Approximately 10,000 sq km (about 3,860 square miles) are considered to be contaminated with more than 15 Ci per sq km. Approximately 100,000 persons, including 30,000 children, reside in the 7,000 sq km of contaminated land in Byelorussia. An estimated 2,000 sq km in Russia and 1,000 sq km in the Ukraine are also reported as being contaminated at this level (*10*). More than 400,000 civilian workers, and an unknown number of military personnel, have been involved in the cleanup operations after the accident (*3*). It is estimated that additional tens of thousands of persons will have to be relocated during the coming years.

Kondrusev (*11*) and Romanenko (*12*) report on the magnitude of the problem and the logistic requirements in dealing with the accident. According to Kondrusev, by the end of first year after the accident more than 20 million background gamma measurements had been made at population centers, and an additional 500,000 samples of drinking water and reservoirs, 700,000 samples of milk and milk products, 120,000 samples of meat and meat products, and 1 million samples of other food products had also been tested. Kondrusev states that potassium iodine prophylaxis (KI) was administered to 5,400,000 people, including 1,690,000 children. Romanenko indicates that 500,000 people, including 100,000 children, were examined and 500,000 hematological and 54,000 hormonal studies were performed. In addition, more than 200,000 determinations of iodine and cesium were conducted.

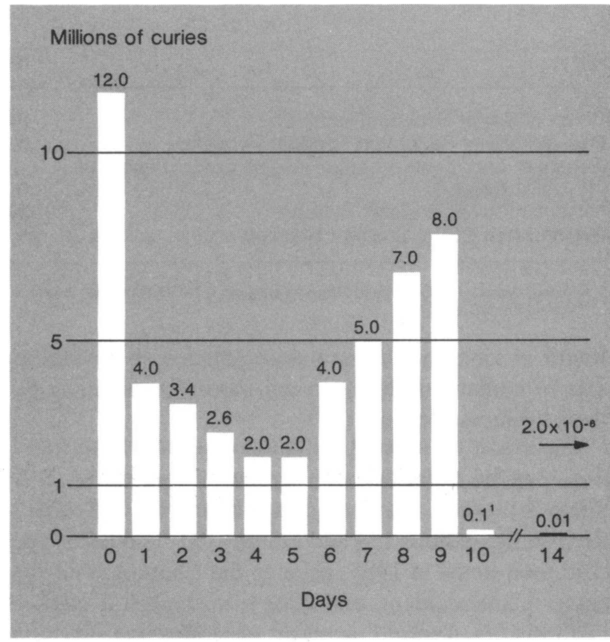
Extent of radioactive exposure. There are four principal pathways of radioactive nuclide exposure (*1*, *4*):

1. external exposure during the cloud passage—1.3 percent of the total collective external dose
2. external exposure from deposited radionuclides—50 percent of the total dose to the Soviet population during the first year and almost 60 percent of the lifetime dose. External exposure of the Soviet population in the first year after the accident constitutes 26.7 percent of the total estimated amount; 20.2 percent is accounted for by ^{131}I and other short-lived isotopes and the remaining 6.5 percent is distributed almost equally (3.5 percent and 3 percent) between ^{134}Cs and ^{137}Cs. For the lifetime dose, the main part will naturally belong to ^{137}Cs, whose contribution to the total external dose from deposited radionuclides varies with the region from 60 percent to more than 90 percent and averages about 70 percent for the country as a whole.
3. internal exposure from inhalation—3.5 percent of the total effective dose was from ^{131}I, other iodine radioisotopes, ^{132}Te, ^{134}Cs and ^{137}Cs.
4. internal exposure from ingestion of ^{131}I, other iodine radioisotopes, ^{134}Cs, and ^{137}Cs. Milk contributed, on average, 6.4 percent of internal exposure. ^{134}Cs comprises 13 percent and ^{137}Cs comprises 20 percent of the total dose over the first year after the accident.

The Soviets indicate that they were able to distribute large quantities of KI to block the absorption of radioactive iodine. Ilyin reports that iodine prophylaxis within the first 3 to 5 days reduced by 50 to 80 percent the amount of radioactive iodine absorbed by the thyroid (*10*). If initial use of KI were subsequent to this time frame, the reduction was estimated to be from 25 to 33 percent of the amount of radioactive iodine absorbed by the thyroid.

The entire population of Pripyat (45,000) was evacuated as were all those living within 30 km of the Chernobyl plant. Il'in estimated that individual whole-body doses for most of the town's inhabitants were about 15–50 mGray (mGy) (1.5–5 rads); for those providing direct services in the contaminated areas, the estimated doses were 130 ± 30 mGy (13 ± 3 rads) (*13*). He reports that iodine prophylaxis (introduced within 12 hours of the accident) for the children in Pripyat resulted in 97 percent of them receiving less than 0.3 Gy (30 rads), with fewer than 1 percent receiving 1.1–1.3 Gy (110–130 rads) to the thyroid. Il'in estimates that the collective dose commitment for the entire population of the country is approximately 326,000 man-sieverts (Sv) (32,600,000 man-rem). This estimate is based on an analysis of field material, with allowances

Daily radionuclide release into the atmosphere from the damaged unit (not including noble gases) at Chernobyl, April 26-May 6, 1986



¹ Recalculated for May 6, 1986.
SOURCE: reference *2*.

for the techniques used. Using this estimate, the increase in the cancer death rate and in the number of genetic defects in the first two generations after the accident is considered to constitute less than a 0.01 percent contribution to the total numbers for each category (*13*).

This estimate is approximately 2.5 times that made by the U. S. Department of Energy (DOE). DOE estimates that of the 3.5 billion inhabitants of the globe, 600 million will develop spontaneous fatal cancers, including up to 6 million fatal cancers from background radiation (1.0 percent of all fatal cancers). In addition, DOE scientists estimate that up to 100,000 fatal cancers will develop from exposure to nuclear tests (0.02 percent of all fatal cancers), and up to 28,000 fatal cancers will develop from the Chernobyl releases (0.004 percent of all fatal cancers) (*4*).

Cleanup workers were initially permitted to receive doses up to 250 mSv (25 rem). This was reduced to 100 mSv (10 rem) per year for the second year and 50 mSv (5 rem) for the third year (*11*). Temporary dose limits of 50 mSv (5 rem) for external and 50 mSv (5 rem) for internal radiation exposure were established for the general population for the first year after the accident. This limit was lowered to a total annual exposure of 50 mSv (5 rem) for the 1987–88 time period.

^{131}I contaminated the drinking water, milk, and other foods. The large-scale screening activities were accompanied by inspections of water and food supplies; those

Table 3. Average ^{90}strontium content in milk, white bread, and potatoes (in 10^{-12} Ci per liter or kilogram) in regions of the Union of Soviet Socialist Republics, in 1985, and the second through fourth quarters of 1986

Region	*Milk*		*White bread*		*Potatoes*	
	1985	*1986 2d–4th quarters*	*1985*	*1986 2d–4th quarters*	*1985*	*1986 2d–4th quarters*
Union of Soviet Socialist Republics	2.9	[1]17.0	4.2	9.9	3.8	8.2
Russian Soviet Federated Socialist Republic	3.3	21.0	6.1	6.2	4.3	6.0
European part (center) of the Russian Soviet Federated Socialist Republic	3.4	50.0	5.2	13.0	4.1	11.3
Ukrainian Soviet Socialist Republic	2.6	23.8	5.1	19.1	3.7	14.0
Byelorussian Soviet Socialist Republic	5.4	[2]55.0	2.4	62.6	6.2	38.0

[1]Without data for the Gomel and Mogilyov Regions of the Byelorussian Soviet Socialist Republic.
[2]3d and 4th quarters only.

found in violation of the public policies about limiting sale of contaminated water and food were fined or had their businesses closed (*11*).

The effect of internal radiation exposure from ingestion may be demonstrated by examining tables 3–5. Table 3 presents the average strontium-90, and table 4 the average cesium-134 and cesium-137, content in specific food items in 1985, prior to the Chernobyl nuclear power plant accident, and after it in the last 3 quarters of 1986 (*14*). Tenfold increases of radioactive strontium in milk, twenty-fivefold increases of strontium in white bread, and sixfold increases of strontium in potatoes in Byelorussia strongly suggest that internal exposure from ingestion will be one of the major problems to be addressed for the foreseeable future. In Byelorussia, during 1986 and 1987, 8.2 percent of meat and meat products sampled, 13 percent of milk, 5.6 percent of milk products, and 7.0 percent of vegetables had the highest levels of excessive permissible radioactive levels (table 5 and reference *15*). These nutritional data explicitly demonstrate the concentration of radionuclides in the food chain by livestock. These data also provide an insight into why many of those living in contaminated areas have shifted to a predominantly starch-based diet. Thus, the fear of contaminated animals and animal products may be responsible for the iron deficiency anemia and other vitamin deficiencies.

Extent of Psychological Problems

Recognizing that psychological problems often accompany major disasters, especially where there are actual and extensive injuries (*16–22*), the Soviet Government requested that the World Health Organization (WHO) convene a Working Group on the Psychological Effects of Nuclear Accidents. This international group met in Kiev, from May 28 to June 1, 1990, and reviewed the Soviet research on psychological sequelae of the Chernobyl NPP accident.

Two basic themes appear in examining the psychological effects of the Chernobyl NPP accident. The first theme deals with change to the community. The accident caused a significant change in many people's lives, especially those who had to be relocated and those who must continue to restrict or modify their activities because of the continued high levels of radioactivity in and near their residences or places of work. Parents are concerned about their children becoming ill. All unexplained illnesses are attributed to radioactivity. Local communities do not trust their central government representatives; they want their own monitoring equipment to determine, for themselves, the levels of contamination. The Soviet Government's payment of 15 or 30 rubles per month per person to assist in purchasing canned goods to supplement the local diet—the payment is higher in areas where the radioactive cesium levels are greatest—appears to have had some unexpected negative consequences on the psychological well-being of the community. The people in affected areas believe that the government does not want to have many areas designated as being highly contaminated, because then it would have to pay out even more money.

The second theme deals with change to the individual. Many people were and are being labelled radiophobic (defined as an inappropriate fear of radioactive materal), even if they live in one of the three zones where there are measurable increases in levels of cesium and other radionuclides (notably strontium) and thus voice appropriate concerns about the potential long-term effects of low dose radiation on their small children or on themselves.

Alexsandrovskij (*23*) reports that immediately after the accident, people were concerned about the direct threat to their lives and health from the explosion and subsequent exposure to radioactive fallout. Family and community disruptions began during the initial evacuation and continued during the temporary relocation and final resettlement periods. He recognizes that the loss of personal and real property, combined with apprehension about possible long-term radiation injury (especially to children), caused a significant amount of stress to par-

Table 4. Average content of cesium (Cs) radionuclides in staple foods and total daily diet in regions of the Union of Soviet Socialist Republics, in 1985, and the second through the fourth quarters of 1986

Region	Milk 1.10−10 Ci per liter		White bread 1.10−10 Ci per liter		Potatoes 1.10−10 Ci per kg		Daily diet[1] 1.10−10 Ci per day	
	1985 ^{137}Cs	1986 ^{134}Cs ^{137}Cs	1985 ^{137}Cs	1986 ^{134}Cs ^{137}Cs	1985 ^{137}Cs	1986 ^{134}Cs ^{137}Cs	1985 ^{137}Cs	1986 ^{134}Cs ^{137}Cs
Union of Soviet Socialist Republics (as a whole)	0.05	[2]17.8	0.06	0.74	0.05	1.2	0.11	11.2
Russian Soviet Federated Socialist Republic	0.04	33.4	0.07	0.31	0.05	0.2	0.12	20.6
European part (center) of the Russian Soviet Federated Socialist Republic	0.06	93.8	0.05	0.44	0.05	0.23	...	...
Ukrainian Soviet Socialist Republic	0.05	9.7	0.12	2.0	0.07	1.14	0.13	9.2
Byelorussian Soviet Socialist Republic	0.28	[3]245.4	0.08	3.7	0.18	19.7	0.56	164.7

[1] USSR permissible levels (as of May 30, 1986).
[2] Without data for the Gomel and Mogilyov Regions of the Byelorussian Soviet Socialist Republic.
[3] Samples were taken predominantly in areas most heavily contaminated with radioactive substances.

ents and to the family unit. Chronic stress, in part due to concern about the long-term effects of radiation exposure, is becoming more evident. The increased incidence of psychosomatic complaints may reflect the high levels of chronic stress in the community. Inadequate and insufficient information about radiation exposure, poor housing and living conditions at the relocation sites, and an incomplete understanding of the government's financial compensation program are additional factors that contribute to the post traumatic stress.

Sergeev identified problems of "psycho-emotional tension and radiophobia" developing after the accident (*24*). He explains away these problems "by the lack of immediate, adequate, and commonly understood information about [the] radiological situation" and indicates that medical personnel are not always adequately trained in these problems.

Arkhanguelskaya and her colleagues (*25*), in the summer of 1988, surveyed 1,500 persons living in the Brjansk region of Russia and concluded that radiophobia occurred because there was

1. a lack of an adequate knowledge base;
2. an overestimation of the harmful effects of low-dose radiation by health care workers, scientists, and the media;
3. a lack of scientific agreement on the stochastic effects of low-dose radiation (the probability that an exposed person will develop cancer);
4. a need to use equipment to measure the harmful properties of radioactive material; and
5. a lack of personal control over the radiation exposure since it occurred as a result of an industrial accident.

The investigators found that half of the physicians and half of the general community surveyed did not believe that a doubling of the background radiation was hazardous. Two-thirds of the total population and

Table 5. Radiomonitoring of food and water in the Byelorussian Soviet Socialist Republic, 1986–87

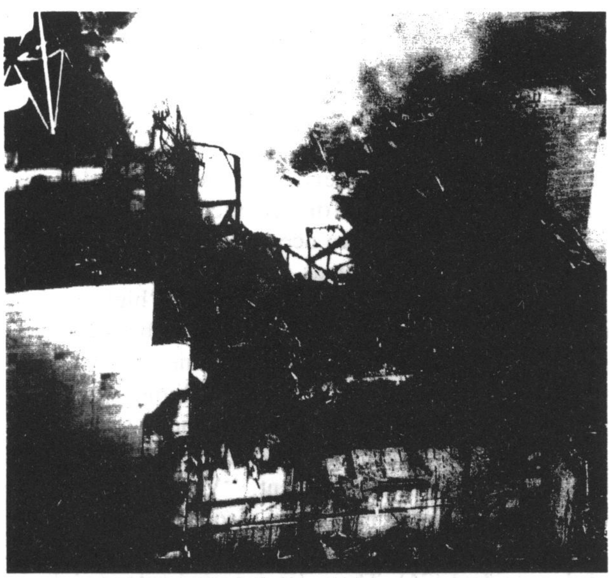
Item	Total of samples	Exceeding permissible levels: Number	Exceeding permissible levels: Percent
Milk	332,718	43,302	13.0
Milk products	115,225	6,438	5.6
Meat and meat products	124,988	10,235	8.2
Vegetables	89,374	6,282	7.0
Fruit	37,838	1,315	3.5
Grain, bread	34,970	806	2.3
Other	147,453	12,104	8.2
Water	799,048	8,760	1.2
Total	1,611,614	89,342	5.5

86 percent of physicians reported that they believe that radiation exposure affects their health. Arkhanguelskaya and her colleagues concluded that more objective and informed media coverage and educational programs are needed, especially for those living in contaminated areas.

Pyatak and his colleagues stated that "high tension, enhanced excitement, stress and radiophobia among some groups" (*26*) accompanied the immediate evacuation of approximately 150,000 people living near Chernobyl. They indicate that these conditions can cause a greater threat to health than the actual increased radiation exposure from the accident. "Vegetative dysfunctions, neurovascular regulation disorders, and changes in the immune system" are believed to be a direct result of the accident (*26*). They also reported extended disorganization of families. However, it is the separation of generations (older family members refused to relocate), rather than a disruption of the nuclear family.

Pyatak and his colleagues recognize that self-reported clinical data may present a distorted picture of the medical care needs of the community and the extent of actual injury from the Chernobyl accident. Some of the somatization observed by local physicians may be sec-

Pripyat, population 45,000, was the largest city affected by the Chernobyl accident. It is expected to be a ghost town for the foreseeable future. "Snow" is radioactive fallout.



Long-term medical, psychological, economic, and social effects of the explosion at the Chernobyl Nuclear Power Plant will require careful study

ondary to the patients' concern about living on contaminated land and consuming contaminated food and water (*23*). Thus, the sudden introduction of comprehensive medical care in a population not accustomed to seeking regular medical care may result in an apparent increase in the prevalence of chronic cardiovascular, gastrointestinal, respiratory, and emotional conditions (*26*). Therefore, Pyatak and colleagues recommend that comparison groups from unaffected regions also be studied to rule out an Hawthorne effect (changes occurring because of the presence of an observer, rather than from the intervention itself).

Post-traumatic stress disorders are being described in some of the residents who remain in areas of moderate or even low level contamination. At present, there is no organized approach to resolving the concerns of these residents. The residents report that there is insufficient objective and trustworthy information about levels of radiation in each of the three zones. The medical personnel do not appear to have been well educated about the acute and chronic effects of high and low dose radiation exposure (*26*). Therefore, it is difficult for the local health care professionals to distinguish between psychological and physical ailments and to develop and implement appropriate therapeutic treatment regimens. Social service resources, such as mental health counselors and social workers, are essentially nonexistent in the USSR.

Needs Assessment

Personnel from the World Health Organization (Copenhagen and Geneva), the International Atomic Energy Agency (IAEA), and the League of Red Cross and Red Crescent Societies (Red Cross) have conducted assessments of the nature and extent of the contamination of land, water, and other resources needed to sustain normal life in the affected regions. The Soviets have permitted the three affected Republics to address independently the problems of radioactive contamination within their borders.

The primary resource deficits, in each of the republics, create a mixture of logistic, financial, and scientific problems.

Logistic problems include the following:

1. insufficient ground transportation, including refrigerated trucks, to bring in sufficient uncontaminated and palatable food supplies.
2. insufficient properly trained medical health care professionals who can deal with the primary and secondary medical illnesses attributable to the Chernobyl NPP accident.
3. insufficient coordination between the three affected republics, exacerbated by their respective nationalist movements.
4. insufficient pharmaceuticals, replacement housing, and retraining and employment opportunities for those that have been and will be relocated.

There is a lack of hard currency to buy medical and nonmedical equipment and pharmaceutical and nonmedical supplies that would facilitate the decontamination, relocation, and social adjustment of those affected by the Chernobyl NPP accident.

Scientific and medical problems include the following:

1. lack of sufficient numbers of well-trained clinical research physicians and scientists who may be dedicated, full-time, to the scientific, medical, and psychological problems that have resulted from the Chernobyl NPP accident. There is a general lack of psychiatric, psychological, and social work services that focus on mental health rather than mental illness—that is, which focus on ameliorating the long-term effects of family disorganization and post-traumatic stress disorders which are expected to evolve as a direct result of the Chernobyl NPP accident.

2. lack of an infrastructure, within each republic and within each local governing district to support prospective longitudinal studies of those who have been evacuated, those living in controlled areas, and those who were or are involved in the cleanup operations.

3. lack of baseline data on the pre-accident health status of those now affected by the Chernobyl NPP accident. The lack of baseline data makes it difficult to calculate the alleged increase in childhood leukemias, thyroid disease, later occurring solid tumors, and so on, that may be predicted to occur as a direct and proximate result of the Chernobyl NPP accident.

4. lack of familiarity with, and access to, current medical and scientific equipment that would facilitate the medical evaluation of those claiming to have been adversely affected by the Chernobyl NPP accident.

5. lack of an organized plan to develop bilateral and multilateral research studies on the short, intermediate, and long-term medical and psychological effects of the Chernobyl NPP accident.

6. lack of an organized treatment and research plan to address the psychological problems that have evolved among those who have been relocated and among those who are residing in one of the three zones where ^{137}Cs remains elevated. The lack of a pragmatic understanding of post-traumatic stress disorder, reactive and situational depressions, and familial strain secondary to the Chernobyl NPP accident will impede the medical treatment and research efforts. Treating physicians and other health care workers must be trained to distinguish between those signs and symptoms that reflect underlying medical pathology and those that are indicative of psychological problems.

Avetisov and coworkers (*27*) estimate that 17.5 million people (including 2.5 million children younger than 7 years) have had some significant exposure to radiation from the Chernobyl accident. Romanenko estimates that the total is half that number (*3*). Regardless of the precise number, the numbers of those affected by the accident are large. The additional numbers of fatal and nonfatal cancers and teratogenic and genetic disorders resulting from this accident should not place an excessive burden on the medical care systems of the affected republics. However, other medical problems, including psychological disorders and the social and economic disruptions of the accident, may require non-Soviet assistance to help minimize the long-term morbidity and mortality directly and indirectly associated with the Chernobyl NPP accident (*28*).

> *'Recognizing that psychological problems often accompany major disasters, especially where there are actual and extensive injuries, the Soviet Government requested that the World Health Organization (WHO) convene a Working Group on the Psychological Effects of Nuclear Accidents. This international group met in Kiev, from May 28 to June 1, 1990, and reviewed the Soviet research on psychological sequelae of the Chernobyl NPP accident.'*

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