11

Congenital Malformations in Rivne, Ukraine

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In 2000, our team launched an international program to establish a registry of every child born in the Ukrainian province of Rivne, located two hundred kilometers west of the site of the 1986 Chornobyl accident. The goal was to monitor the population frequency of congenital anomalies. Our team performed ultrasound examinations on nearly 70 percent of pregnant women in Rivne. We reviewed all examinations of stillborn children, and we had newborns examined by trained neonatologists and infants with visible congenital anomalies later monitored by pediatricians and, in most cases, clinical geneticists. We recorded anomalies in children up to the age of one according to methods approved by the Ukrainian Ministry of Health and EUROCAT, a consortium of thirty-eight European systems monitoring congenital anomalies. Our partnership with EUROCAT allowed us to compare congenital malformation rates in Rivne with those elsewhere in Europe. Within two years,

it became evident that some congenital anomalies occurred more frequently in northern Rivne-Polissia, henceforth referred to as Polissia.

Polissia is heavily polluted by radiation from the accident at Chornobyl, and there are two additional nuclear power plants of the same age and type as Chornobyl that remain potential sources for further pollution. The area's forested wetlands are geologically different from the fertile plains of southern Rivne, and the soil in Polissia transfers a greater proportion of radioactivity to plants, thereby increasing the quantity of radioactive elements in wood, vegetables, milk, meat, and other products used by the local population. Furthermore, seasonal flooding and frequent forest fires redistribute radioactive materials.

Since 1986, the isolated native population has had no option but to come in contact with radioactive materials. Locally produced milk, cheese, potatoes, and other foods in Polissia are polluted by radioactive elements found in soils. Approximately 67 percent of households burn local wood for cooking or for heating. This wood is a source of radioactive smoke, which is inhaled by both adults and their children. Families also use wood ash to fertilize their home garden plots, further concentrating the radioactive materials as humans and domestic animals consume homegrown vegetables. During harvest, pregnant women are often given easier tasks such as burning dried stems of potato plants containing cesium-137 and strontium-90, which are inhaled as smoke. Consequently, everybody in Polissia has been, and

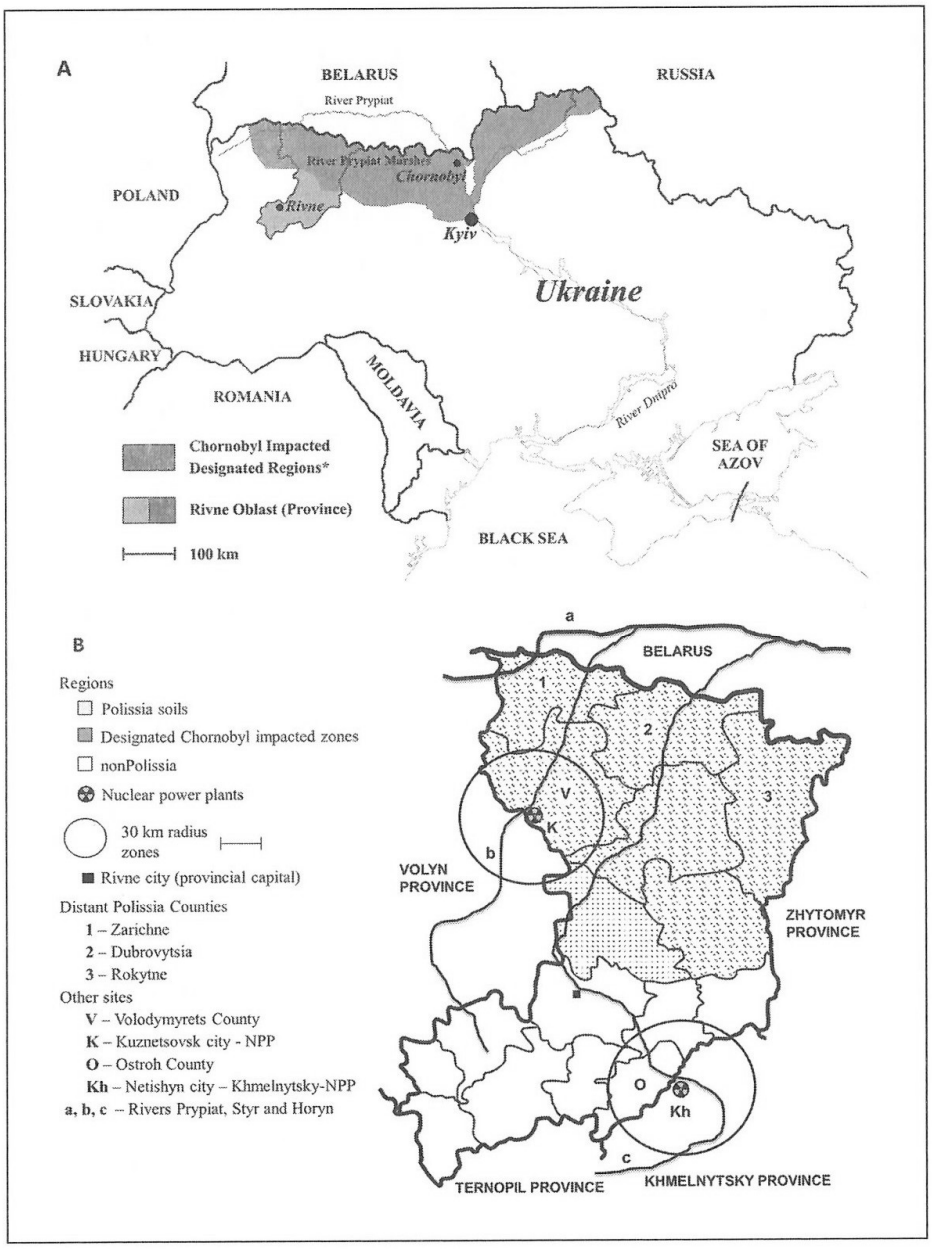

Figure 11.1. Maps of Regions Impacted by Ionizing Radiation from Chornobyl

continues to be, exposed to radiation, with a growing proportion of the population exposed since the moment of their conception by parents who have themselves been exposed to radiation.

Sample	Measurements		
	^{90}Sr, Bq/kg		^{137}Cs, Bq/kg
	Initial	Repeat	
A	43.4 ±17.2	46.8 ±21.4	88.3 ±36.4
B	49.9 ±17.9	32.1 ±24.1	63.6 ±39.3
C	41.3 ±19.9	46.4 ±19.2	24.0 ±22.0
D	82.3 ±21.3	72.2 ±20.0	
E	88.3 ±23.1	84.4 ±28.1	46.1 ±34.6
F	95.6 ±23.1	143.2 ±29.6	
G	327.2 ±86.6	87.3 ±25.1	54.8 ±31.4

Figure 11.2. Radiometry of Dried Potato Stems from Rivne-Polissia Region

When cesium is absorbed by the body, it is excreted in a relatively short time—approximately one year. Strontium, on the other hand, is quickly absorbed by a growing embryo, fetus, and child, and is bound to structures that normally bind calcium, such as bone and teeth, where it can remain for a lifetime.

We determined that an average pregnant woman in Polissia ingests 268 becquerels daily, which is above the upper daily limit of 210 becquerels set for adults by the Soviet Union. The cumulative upper total body count of becquerels for adults was set at 14,800 and for individuals under fifteen was set at 3,700. It is well established that growing organisms are more sensitive to ionizing radiation damage. The upper limit for the rapidly developing human embryo-fetus has yet to be determined.

To simplify the process of estimating radiation exposure and to enhance the accuracy of the estimates, we opted to directly measure whole-body counts of becquerels, which reflect the quantity of cesium-137 incorporated by pregnant women. (Detecting strontium is much harder.) The whole-body count of cesium-137 incorporated by 48 percent of 1,156 pregnant women in Distant Polissia (the three counties farthest north) was above the 3,700-becquerel limit set for individuals under fifteen. Among 6,026 pregnant women investigated, only those from Polissia accumulated significant levels of cesium-137.

	Distant Polissia[a]	Non-Distant Polissia[b]	Non-Polissia[c]
Pregnant Women[d]	1,156	2,534	2,336
Above Bq norm[e] (%)	557 (48.2)	155 (6.1)	3 (0.1)
Children[f]	1,338	3,671	1697
Above Bq norm (%)	162 (12.1)	50 (1.4)	1 (0.1)
Adult Males[f]	2,117	5,885	4,325
Above Bq norm (%)	136 (6.4)	22 (0.4)	-

(a) Includes three most northern counties of Polissia.
(b) Includes four other counties of Polissia.
(c) Includes all other counties except for those in (a) or (b).
(d) Pregnant women seeking prenatal ultrasound examinations at the Rivne Regional Diagnostic Center (2008–2011) who volunteered to undergo the procedure.
(e) Official limits (norms) are 3,700 and 14,800 Bq of cesium-137 for subjects under fifteen years of age and adults, respectively.
(f) 2000–2011 data.

Figure 11.3. Whole Body Counts of Incorporated Cesium-137 Radiation by Rivne Diagnostic Center's Ambulatory Outpatients

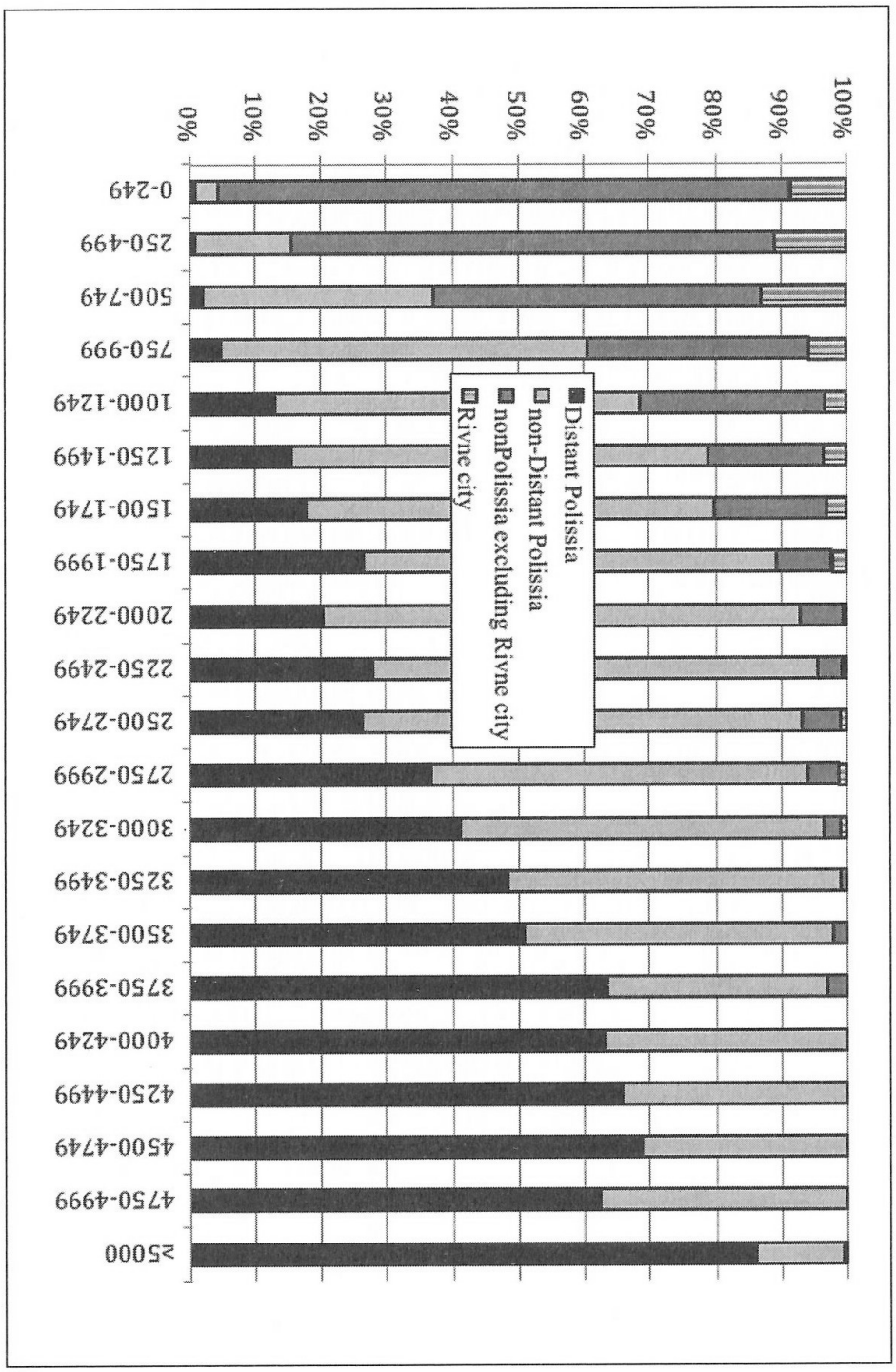

Figure 11.4. Residence and Whole Body Counts (WBC) of Incorporated Ionizing Radiation (Bq 137Cs) Among 9,146 Pregnant Women in Rivne Province (2008-2012)

Area of Residence	Women	AE[1]	OR	P	CL
Polissia	852	13 (1.53)	-	-	-
Non-Polissia	1,417	67 (4.73)	0.31	<0.001	0.16, 0.58
Rivne City	566	36 (6.36)	0.23	<0.001	0.11, 0.45
Khmelnytsky City	1,062	47 (4.43)	0.33	<0.001	0.17, 0.63

Figure 11.5. Alcohol Consumption by Pregnant Women (%)

Category	Polissia	Non-Polissia	Combined
FASD[a]	37[a]	42	79[b]
and Microcephaly[c]	9	11	20
Males	7[e]	6[g]	13
Females	2[f]	5[h]	7
No microcephaly	27	31	58
Males	12	19	31
Females	15	12	27
Gestational age (weeks)[d]			
<35	8	10	18
35–37	9	14	23
≥38	9	6	15
Birth weight (grams)			
<2,500	21	25	46
≥2,500	6	6	12
Prenatal diagnosis	6	6	12

Figure 11.6. All Individuals with Fetal Alcohol Spectrum Disorder (FASD)—Non-Population-Based Observations

The most significant negative impact of radiation on a developing embryo includes anencephaly, which is a developmental deficiency in the skull and in the brain, and microcephaly, which, according to our strict definition, is a reduction in head circumference of three standard deviations below the norm. We found that the frequency of microcephaly was statistically significantly higher in Polissia. We measured the head circumferences of all newborns at birth in one county in Polissia as well as in Rivne City outside Polissia. The head circumferences of the newborns in Polissia were statistically significantly smaller than in Rivne City. We then measured the head circumferences of newborns in another Polissia county and compared these with the head circumferences measured in every county outside Polissia. The results again indicated that head circumferences were statistically significantly reduced in Polissia.

A teratogen is any environmental factor that can cause malformations or developmental alterations. In Ukraine, common teratogens are radiation and alcohol. Both can cause similar congenital anomalies, such as severe or minimal microcephaly. Our program studied not only radiation but also alcohol teratogenicity, partnering with the Collaborative Initiative on Fetal Alcohol Spectrum Disorders (CIFASD), which monitored alcohol use in pregnant women in Rivne and assessed its potential developmental impact on their children. We concluded that alcohol was not a likely cause of higher rates of microcephaly or reduced at-birth head circumferences in Polissia. An analysis of alcohol use by

Figure 11.7

Incidences and Rates of Neural Anomalies

	Births	Neural Tube Defects	Microcephaly	Microphthalmia
Europe (2000–2008)*	6,392,138	5,860 (9.2)	1,280 (2.0)	486 (0.8)
Rivne (2000–2009)	145,437	303 (20.8)	42 (2.9)	27 (1.9)**
Not impacted by Chornobyl	80,976	138 (17.0)	12 (1.5)	9 (1.1)
Impacted by Chornobyl	64,461	165 (25.6)	30 (4.7)	18 (2.8)**

Rates per 10,000 live births plus stillbirths.

* Data from thirty-one registries (Styria, Austria; Antwerp, Belgium; Hainaut, Belgium; Zagreb, Croatia; Odense, Denmark; Paris, France; Strasbourg, France; Saxony-Anhalt, Germany; Hungary; Cork and Kerry, Ireland; Dublin, Ireland; southeast Ireland; Campania, Italy; Emilia-Romagna, Italy; northeast Italy; Sicily, Italy; Tuscany, Italy; northern Netherlands; Norway; Greater Poland; southern Portugal; Barcelona, Spain; Basque Country, Spain; Vaud, Switzerland; East Midlands and Yorkshire, England; North West Thames, England; northern England; southwest England; Thames Valley, England; Wessex, England; and Wales).
** Excludes three instances of microphthalmia, one in combination with neural tube defects and two in combination with microcephaly.

pregnant women clearly shows that alcohol consumption in Polissia is statistically significantly less frequent than outside Polissia.

The range of human congenital anomalies is vast. In Rivne, the rates of sentinel anomalies, such as Down syndrome and cleft lip (with or without associated cleft palate), are well established. The rates of these anomalies in Polissia are similar to the rest of Rivne and to those reported across Europe. On the other hand, the rates of conjoined twins, teratomas, and neural tube defects are elevated in Rivne and even more so in Polissia. The rates of these anomalies in Polissia are among the highest in Europe. Many experts believe that the anomalies are blastopathies, which are anomalies evident in a fertilized ovum (blastula) before it develops into an embryo and it implants in the womb. Recent studies in molecular embryology suggest that any factors that delay the development of a fertilized egg—for instance, radiation damage—may result in the duplication of the axis of an embryo, causing twinning or other blastopathies such as anencephaly. Recent studies also show that female embryos reach developmental stages at a slower pace, which may render them more vulnerable to the kind of blastopathies observed in Rivne.

The Chornobyl accident turned into a catastrophic disaster in great part because of the inadequate response by the Soviet authorities and their chosen experts. These experts, for example, claimed that people in Ukraine who

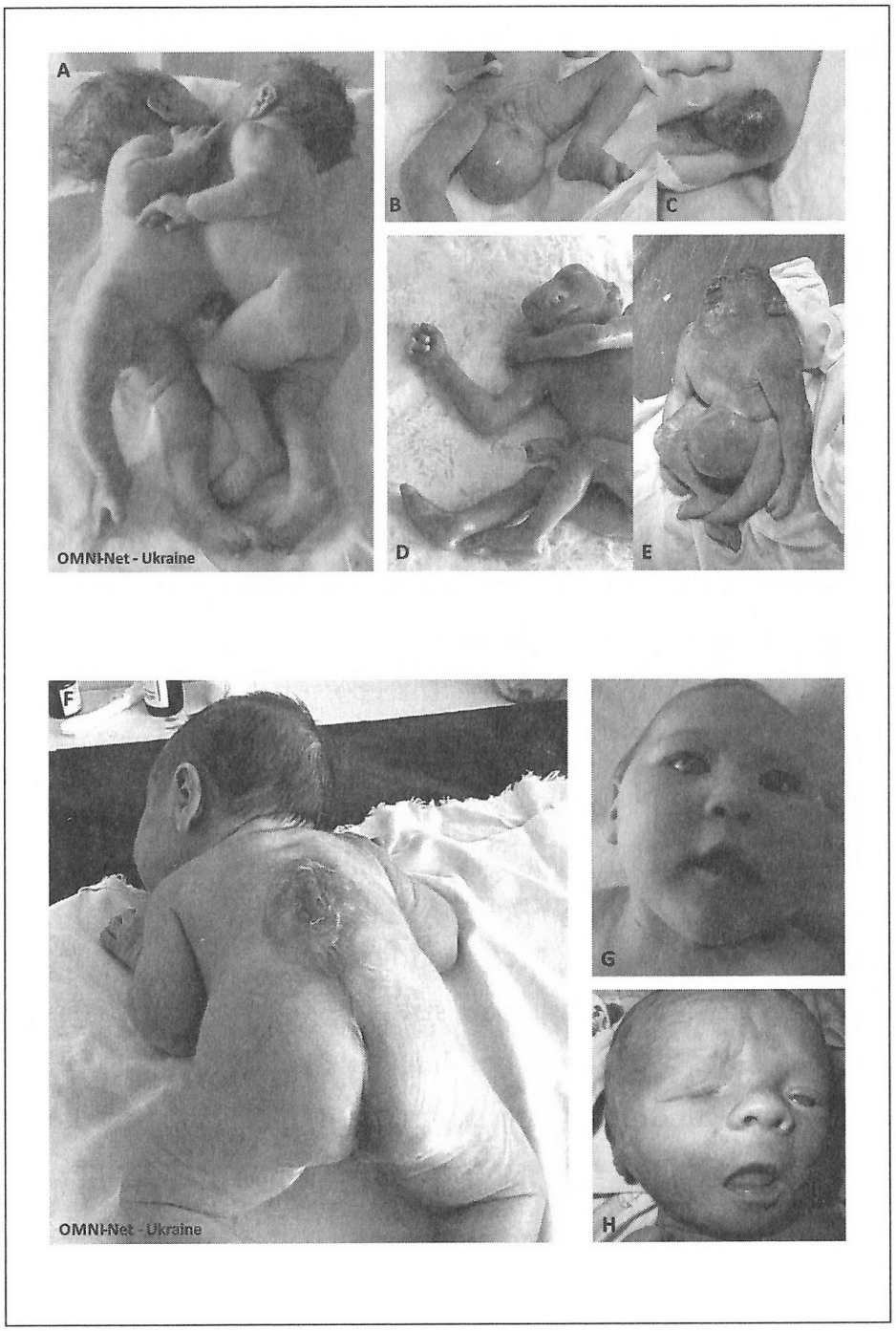

Figure 11.8. Radiation-induced anomalies include (A) conjoined twins, (B) and (C) congenital teratomas, (D) anencephaly, (E) iniencephaly, (F) spina bifida, (G) microcephaly, and (H) microphthalmia.

were impacted by the radiation suffered merely from radiophobia—an abnormal fear of ionizing radiation. Yet evidence of the profound impact of the Chornobyl disaster on Ukrainians can be found in the dramatic drop in the birthrate, which persists even now. The Soviet Union ignored the severe impact of radiation pollution on the population in Polissia—a mistake corrected only in 1991 after Ukraine became independent.

We are aware that reports of elevated rates of congenital anomalies in regions impacted by radiation from Chornobyl are greeted with skepticism and often dismissed. There are many reasons for this, among them the persistent denials by organizations such as the International Atomic Energy Agency (IAEA), the World Health Organization (WHO), and the United Nations Development Programme (UNDP). The IAEA asserts that "because of the relatively low doses to residents of contaminated territories, [there is] no evidence or likelihood of decreased fertility . . . no evidence of any effect on the number of stillbirths, adverse pregnancy outcomes, delivery complications or overall health of children. . . . A modest but steady increase in reported congenital malformations . . . appears related to better reporting, not radiation."

This assertion is not based on actual investigations in areas impacted by Chornobyl but mostly on the results of previous investigations in Hiroshima and Nagasaki, which were sponsored by the Atomic Bomb Casualty Commission

(ABCC). A critical difference between the Hiroshima-Nagasaki and Chornobyl radiation impacts is that radiation exposure from the atomic bombs was external, intense, and short. There was virtually no residual radiation. In contrast, the radiation exposure from Chornobyl was internal, low, and continuous. The impact of radiation on health is cumulative. The average pregnant woman in Polissia absorbs at least 250 becquerels per day, which by the age of twenty-five is equivalent to over 2,200,000 becquerels. A growing number of parents have been exposed to radiation since their own conception.

For the most part, ABCC-sponsored studies were performed before the establishment of the American and later Japanese and European teratology societies, which developed the current criteria for scientific investigations into the human environmental causes of congenital malformations. Launched nearly five years after the bomb blasts, the studies were not based on the exposed population. They were based on children who had not been exposed to radiation but whose parents had been irradiated by the blasts and had survived the explosions and famine that followed.

Two sets of ABCC-sponsored investigations focused on congenital malformations among the children of pregnant women at the time of the blasts. The first involved 205 almost-five-year-old children exposed in utero to the bomb blasts. Clinical examinations without a control group showed that twenty-four (12 percent) had anomalies, including six

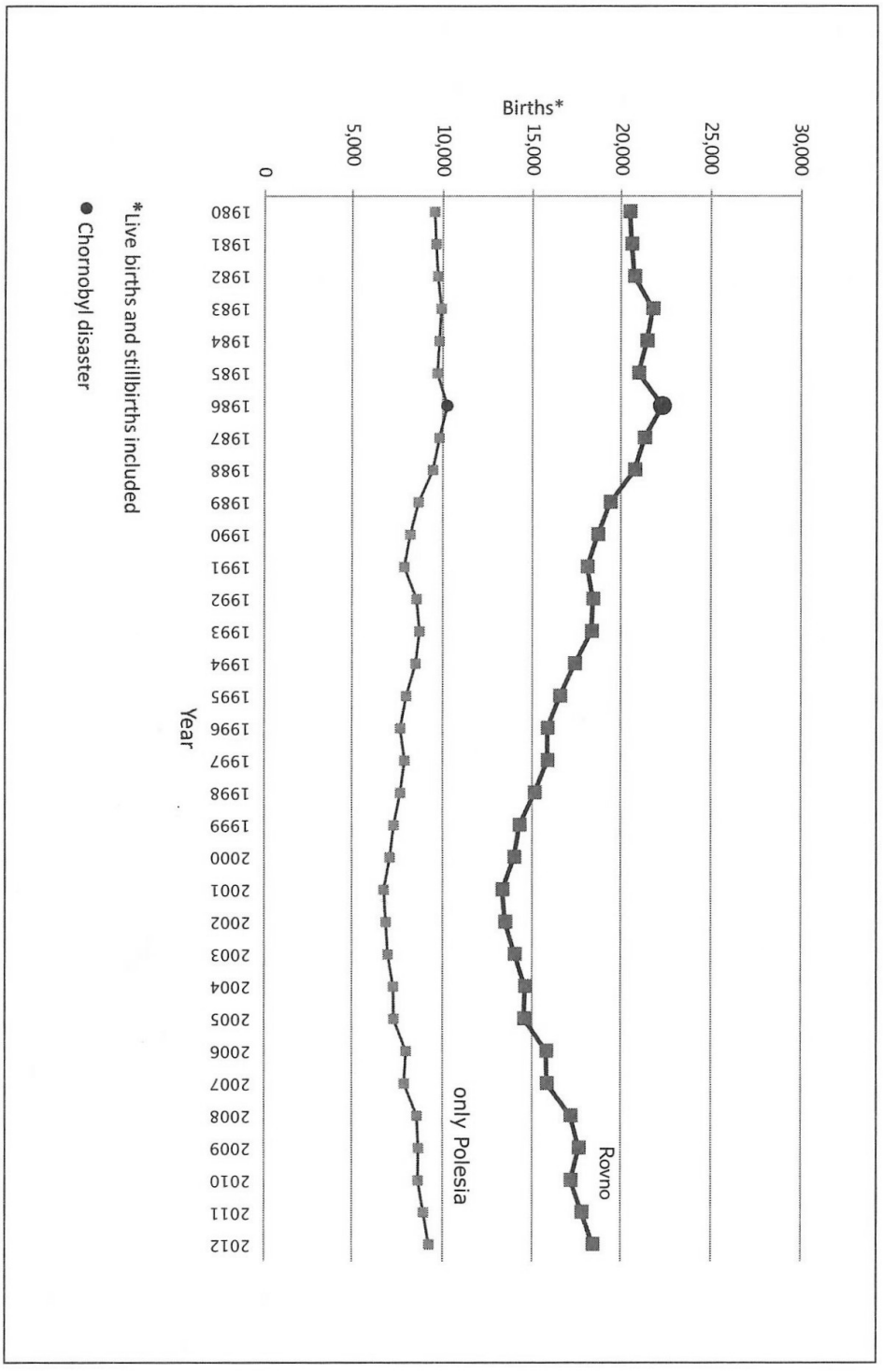

Figure 11.9. Yearly Birth Rate in Rivne and Polissia from 1980 to 2012

(3 percent) instances of microcephaly associated with mental subnormality. Another set of studies focused on mental retardation. They included information on microcephaly but did not focus on congenital malformations. The study group consisted of 1,613 children exposed to the atomic blasts during various states of gestation. Significant effects were evident among those who survived infancy and were exposed at eight to fifteen and sixteen to twenty-five weeks after ovulation, namely, reduction in cognitive function, severe mental retardation, and reduction of head size or obvious microcephaly.

In 1987, it became possible to assign updated dose estimates from a database known as DS86. The analysis estimated a decrease of 25–29 IQ points per gray[1] of uterine absorbed radiation dose. Doses as low as one thousandth of a gray impact the migration of brain neurons. One gray is almost the equivalent of a sievert and a thousandth of a gray, or millisievert, is the unit often used to express safety limits of exposures to radiation. In Europe, the limit for people exposed as part of their occupation is 20 millisieverts per year and 0.3 millisieverts per year for the gonads and uterus respectively. Implicit in these limits is that the gonads and the embryo are at least a hundred times more sensitive to radiation damage than other cells of the adult body. Also implicit is that the exposure is external to the body.

In Polissia, exposure comes through the inhalation and ingestion of radioactive elements, which promptly reach the

blood that nourishes the rapidly growing embryonic tissues. It is logical to consider that the high rates of anencephaly, microcephaly, and microphthalmia are likely to be caused by the long-term internal exposure of embryos to low radiation levels in Polissia. This is supported by observations made shortly after the Chornobyl accident. A series of clinical observations indicated a rise in the frequency of congenital malformations, especially anencephaly. Other investigations showed that congenital malformation rates were not elevated among populations residing in regions of Western Europe remote from Chornobyl.

There are two U.S. studies and one British on ionizing radiation exposure from nuclear power plants. The U.S. studies were conducted by the same reputable scientists sponsored by the Centers for Disease Control and Prevention (CDC). Both these studies sought to determine the teratogenic impact of ionizing radiation near the Hanford nuclear complex in Washington State. One study detected higher neural tube defect rates in two counties near the nuclear complex and the other demonstrated higher rates of neural tube defects in parents exposed in their occupation to low levels of radiation. The scientists considered the studies to be sound but rejected the results as "falsely positive conclusions." Among the reasons for this was that the results contradicted those of the ABCC-sponsored studies.

The British study looked at fathers employed at the Sellafield nuclear reprocessing complex in Cumbria in

northern England. The results showed a positive association between the total exposure to external ionizing radiation before conception and a higher risk for stillbirths with a congenital anomaly and for stillbirths with neural tube defects.

Two other points deserve attention. In 2013, there were concerns about unusually high rates for neural tube defects in regions close to the Hanford atomic complex, while in northern England and Wales, the frequency of neural tube defects as well as conjoined twins and microcephaly was, after Polissia, among the highest in Europe. The Washington State Department of Health noted twenty-seven confirmed NTD-affected pregnancies from 2010 to 2013 among women residing in a three-county area near Yakima, which is about seventy miles away from the Hanford site. Among the twenty-seven pregnancies, twenty-three were instances of anencephaly, equivalent to a population rate three times higher than the national estimate. This cluster of congenital malformations is under investigation. In Britain, the impact of the Chornobyl radioactive fallout was particularly significant in Cumbria, Wales, and southwest England. The neural tube defects and microcephaly rates in these regions tend to be among the highest in Europe. The central regions of Scandinavia were also heavily impacted by the fallout. Two independent studies, one in Norway and the other in Sweden, showed that individuals most exposed in utero to radiation from Chornobyl demonstrated significant negative impacts

on their cerebral functions. These results are consistent with our observations of the reduced head circumferences of newborns in two Polissia counties.

Under the precautionary principle endorsed by medical professionals, those who dictate or advocate policies in the absence of conclusive scientific evidence or consensus have the responsibility to demonstrate that any proposed, imposed, or advocated policies are not harmful to the public or the environment. Official claims that Chornobyl's ionizing radiation is not teratogenic contradict this precautionary principle. Furthermore, the repeated unsubstantiated denial of Chornobyl's teratogenic impact or even potential impact

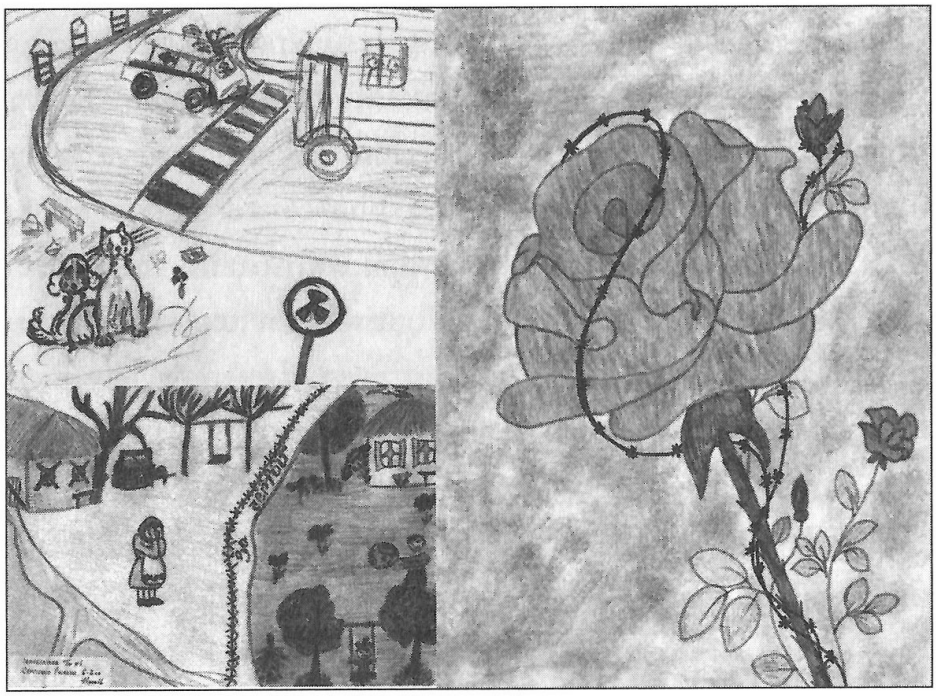

Figure 11.10. As these drawings show, the Chornobyl disaster has had a profound impact on the psyche of children in an elementary school in Ukraine.

discourages attempts to investigate their validity. We hope that through our studies and the events in Fukushima, Japan, will encourage agencies to endorse studies concerned with teratogenic impacts of low-dose ionizing radiation. We also hope that the results of this study provide a starting point for prospective studies of regions impacted by Chornobyl and Fukushima.

CRISIS WITHOUT END

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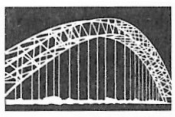
From the Symposium at the New York Academy of Medicine, March 11–12, 2013

Edited By

Helen Caldicott



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