FRENCH-GERMAN INITIATIVE
FOR CHERNOBYL

HEALTH PROJECT

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**FRENCH-GERMAN INITIATIVE**

**FOR CHERNOBYL**

**HEALTH PROJECT**

Margot TIRMARCHE Coordinator

Report DRPH/2006-10

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The work conducted on the health of populations exposed to radiation as part of the French-German Initiative (FGI) focused on the principal health indicators that might show an excess incidence of cancer after a relatively long latency period. No clear difference in leukemia incidence trends was observed between exposed and unexposed regions in Ukraine, Belarus or Russia. Incidence rates for solid tumors tended to increase similarly over time in all regions. In contrast, the incidence rate of thyroid cancers in the exposed regions rose substantially, especially among those younger than ten years at the time of the accident. Analysis of the national cancer registry in Belarus revealed a sharp rise in the number of thyroid cancers recorded in children younger than 15 years, which began at the start of the 1990s. It also showed an unmistakable increase in these cancers since 1998, in the 15-29 year age group. In this exposed population, therefore, the risk of thyroid cancer continues 20 years after the accident. Trends for congenital malformations did not differ discernibly between the exposed and unexposed regions.

**KEY-WORDS** CHERNOBYL ACCIDENT, HEALTH EFFECTS, THYROID CANCER
## PARTICIPANT LIST

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FRENCH-GERMAN INITIATIVE: HEALTH PROJECT

The ministers of the environment of France and Germany launched the French-German Initiative (FGI) on April 12, 1996, to establish a cooperative program to work with Belarus, Russia and Ukraine to improve understanding of the consequences of the Chernobyl accident in these countries and to make reliable data available for policy-makers, researchers, and all those concerned by the accident. The activities conducted as part of the FGI took place from 1997 through 2004. The IRSN (Institute of Radioprotection and Nuclear Safety) in France and the GRS (German nuclear plant and reactor safety authorities) were assigned to coordinate all FGI activities.

Numerous scientific teams in Belarus, Russia and Ukraine were involved in this health project in two capacities, in providing their data to construct a database of important information and in conducting studies on the subjects considered by the FGI scientific coordination to be of the highest priority. The following teams participated:

- Ukrainian Research Institute of Oncology of the Academy of Medical Sciences of the Ukraine - Kiev, Ukraine
- Ukrainian Research Institute of Nutrition (URIN) - Kiev, Ukraine
- Ukrainian Research Center for Radiation Medicine - Kiev, Ukraine
- Medical Radiological Research Center of RAMS - Kaluga oblast Russia
- Belarussian Center for Medical Technologies, Computer Systems, Administration and Management of Health (BELCMT) - Minsk, Belarus
- Belarussian Institute for the Protection of Motherhood and Childhood - Minsk, Belarus
- Institute of Power Engineering Problems - Minsk, Belarus
- Research Institute for Haematology and Blood Transfusion - Minsk, Belarus
- Belarussian Institute for Hereditary Diseases (BIHD) - Minsk, Belarus
Pierre Verger (1997-2001) and Margot Tirmarche (2002-2004) from IRSN coordinated the project in collaboration with Professor Albrecht Kellerer of the University of Munich.

The French and German scientists who participated were:

- Susanne Becker / University of Munich
- Bertrand Gagnière / CIRE Ouest - Rennes
- Albrecht Kellerer / University of Munich
- Reinhild Pott-Born / University of Munich
- Nathalie Rutschkowsky / IRSN/ International Relations
- Madeleine Valenty / IRSN/ Epidemiology Laboratory
- Hilaire Mansoux / IRSN/ Radiological Protection Division
- Brigitte Franc / Hôpital Ambroise Paré - Boulogne
- Elisabeth Robert-Gnansia / European Genomutation Institute
- André Briend / CNAM - Paris

Christine Brun-Yaba and J-L. Frichet of Riskaudit and Isabelle Calmont (IRSN) provided logistic support.
SUMMARY

The work conducted on the health of populations exposed to radiation as part of the French-German Initiative (FGI) focused on the principal health indicators that might show an excess incidence of cancer after a relatively long latency period.

No clear difference in leukemia incidence trends was observed between exposed and unexposed regions in Ukraine, Belarus or Russia.

Incidence rates for solid tumors tended to increase similarly over time in all regions.

In contrast, the incidence rate of thyroid cancers in the exposed regions rose substantially, especially among those younger than ten years at the time of the accident. Analysis of the national cancer registry in Belarus revealed a sharp rise in the number of thyroid cancers recorded in children younger than 15 years, which began at the start of the 1990s. It also showed an unmistakable increase in these cancers since 1998, in the 15-29 year age group. In this exposed population, therefore, the risk of thyroid cancer continues 20 years after the accident.

Trends for congenital malformations did not differ discernibly in the exposed and unexposed regions.
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1. INTRODUCTION

When the FGI began in 1996, doctors in Belarus, Ukraine and Russia had already reported a clear increase in the incidence rate of thyroid cancer in young children, especially those exposed to radioactivity released during the accident at Chernobyl. One goal of the researchers involved in the FGI was to extend the follow-up of those exposed as children and to observe the health effects occurring among them as they reached adolescence and young adulthood. All age categories were considered for the other types of cancers, including leukemia. Some studies served to validate the quality and exhaustiveness of cancer registries [Franc et al., 2003]; they also enabled researchers to consider some of the cofactors (such as quality of screening) that may have influenced the increased incidence of some diseases.

An important strong point of the FGI is that it aimed to assess cancer incidence rather than simply mortality: for some diseases, incidence is a much more pertinent indicator than mortality, which depends on the quality of the death certificate.

Exposure to the accident at Chernobyl was different from that at Hiroshima and Nagasaki. In many of the oblasts contaminated by deposits from the accident, individuals simultaneously underwent internal contamination and external irradiation. FGI studies described health effects principally by comparing the populations of highly contaminated regions with less exposed populations. The FGI also studied the population of workers who participated in the site cleaning operations or who entered into the zone in a 30-km radius from the site, generally referred to as the “liquidators”.

The results presented here come from teams of researchers in Belarus, Russia and Ukraine involved in the FGI. All data were transferred into a common database administered in Kiev.

The principal results concern:

- leukemia incidence
- thyroid cancer incidence
- solid cancer incidence
- effects of the exposure of very young children
- dietary and nutritional practices in Ukraine
- dose reconstruction for liquidators.

At the international conference held in Kiev in October, 2004, researchers from the institutes involved presented all of the work conducted during these seven years of collaboration.
2. ANALYSIS OF THE INCIDENCE OF LEUKEMIA

Since the first publications of the study of Hiroshima and Nagasaki survivors, leukemia has been considered to be a relatively early indicator of the health risk associated with ionizing radiations. Leukemia incidence was studied either at the national level or in several oblasts, by comparing contaminated with only slightly contaminated regions. To the extent possible researchers looked for reliable data for the period before 1986 to compare incidence rates before and after the accident.

2.1 BELARUS: ANALYSES

In Belarus, the national standardized incidence rate (annual rate per 100,000 inhabitants) of acute leukemia between 1986 and 1992 was little different from that for the pre-accident period (1979-1985). The rate for 1993-1997 was lower than that for the two preceding periods (table 1).

The rate of chronic leukemia increased during the 1986-1992 period. Examination of different histologic types indicates that this increase concerns especially chronic lymphocytic leukemia (CLL), although it is not in principle linked to radiation exposure. For chronic myeloid leukemia (CML), the significant increase observed for 1986-1992 compared with the period preceding the accident ($p_{2.1} < 0.01$) did not continue into the 1993-1997 period (table 2).

Table 1. Annual incidence rate per 100,000 of acute leukemia in the adult Belarus population (three study periods)

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<td>Rate</td>
<td>2.71 ± 0.09</td>
<td>2.87 ± 0.10</td>
<td>2.58 ± 0.11</td>
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Table 2. Annual incidence rate per 100,000 of chronic myeloid leukemia in the adult Belarus population (three study periods)

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<td>Rate</td>
<td>1.33 ± 0.05</td>
<td>1.60 ± 0.07</td>
<td>1.39 ± 0.08</td>
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The polycythemia rate (that is, the rate of elevated red blood cell counts) after the accident increased significantly over that of the preceding period (table 3).
Table 3. Annual incidence per 100 000 of polycythemia in the adult Belarus population (three study periods)

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<td>Rate</td>
<td>0.56 ± 0.04</td>
<td>0.72 ± 0.05</td>
<td>0.85 ± 0.04</td>
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<td>Significant differences</td>
<td>P_2&lt;sub&gt;1&lt;/sub&gt; &lt; 0.05</td>
<td>P_3&lt;sub&gt;1&lt;/sub&gt; &lt; 0.001</td>
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In the most contaminated regions of Belarus (Mogilev, Gomel and Brest), the time trends for the polycythemia incidence rate were the same as in the other oblasts. Moreover, the standardized rates of different types of leukemia for each study period remained similar to those of Vitebsk, the control oblast. According to V.N Gapanovitch's team [1], numerous factors may explain the increases after the accident. The contribution of ionizing radiation remains difficult to assess because there is a latency period of at least 2 years before cases of leukemia detected can be attributed to radiation. E. Ivanov has also suggested that if the same diagnostic protocol had been used before and after the accident, the pre-1986 incidence rate would have been higher: the rates of acute leukemia for which the cell type was unknown was 4 times higher during the pre-accident period than in 1993-1997.

2.2 UKRAINE: ANALYSES

Two independent analyses made it possible to compare trends before and after the accident in Ukraine.

One of the studies used incidence data from the oblasts of Zhytomyr and Kiev, considered the most contaminated in Ukraine [2]. The researchers observed a slight augmentation in the incidence rate of leukemia compared with the period before the accident (figure 1). Nonetheless, differences with the national rate are quite small, overall and for each sex considered separately.
As the figure shows, comparison with the national registry is possible only from 1990, because the registry is incomplete for the earlier period (national validation).

The standardized incidence rates for these regions are close to the rates for the rest of Europe and, like them, increase with age. A comparative analysis of the different types of leukemia shows that incidence rates for 1987-1992 and 1993-1999 are moderately higher than for 1980-1986, in particular, for both acute lymphocytic and acute myeloid leukemias (ALL and AML, respectively).

The other study examined incidence data from the contaminated oblast of Chernihiv and the not contaminated oblast of Sumy [3]. Before and after the accident, leukemia incidence rates fluctuated between these zones. Nonetheless, the incidence observed in the contaminated zone never exceeded the national mean. Regardless of place of residence, leukemia incidence rates were higher in men than in women.

According to V.G. Bebeshko's team, incidence rates for the three successive periods from 1980 through 2000 did not differ substantially for men or women in any of the regions, contaminated or not (figures 2 and 3) [3].

The rate rose after the age of 44 years (and was highest for those 65-69 years) during all three periods. In the contaminated area, incidence rates for men older than 44 years were higher after the accident than before.
Comparison of rates for children aged 0-10 years showed no disparities in the contaminated and control regions. ALL predominated in children and CLL in adults.

2.3 RUSSIA: ANALYSES

In Russia, V. Ivanov's team [4] detected no excess leukemia incidence between 1986 and 1998 in the highly contaminated regions of Bryansk compared with the general Russian population (figure 4). The
number of cases that may be due to exposure to ionizing radiation is very slight and cannot be
distinguished from statistical fluctuations.

Figure 4: Annual leukemia incidence rate as a function of age at diagnosis, 1986-1998, in Russia
and in Bryansk oblast [4]

Similarly, within oblasts, comparison of leukemia incidence rates in the highly contaminated Bryansk
oblast and the control oblast of Kaluga shows no significant differences in either all types of leukemia
or all types of leukemia except CLL. Note, however, that the analysis is particularly difficult because of
the low number of cases per year and the very heterogeneous distribution of cases in the different age
groups.

In the highly contaminated oblasts, the incidence rate for children aged 0-14 years at diagnosis fell
slightly contaminated oblast of Kaluga showed the reverse time trend (figure 5).
3. ANALYSIS OF THE INCIDENCE OF THYROID CANCERS

Thyroid cancer is a relatively rare disease (annual incidence rate on the order of 5 per 100,000 in adults and 0.2 per 100,000 in children) with a low mortality rate (approximately one tenth of the incidence rate). Thus only meticulous recording of its incidence can reveal its excess in a population. Belarus physicians reported by 1990 that the incidence rate of thyroid cancer was substantially higher in young children there than in other countries. It has long been known that individuals who undergo external thyroid irradiation during childhood have a significantly elevated risk of thyroid cancer. The increased risk of thyroid cancer associated with internal exposure to radioactive iodine was not well documented then. Nonetheless, the thyroid gland's ability to take up iodine in its immediate environment indicated the likelihood of elevated thyroid doses in the conditions of high contamination around the Chernobyl plant: the thyroid dose for Belarussian children may have been 100 times higher than the dose to other organs. At equal contamination levels, thyroid doses are higher in children than in adults. The minimum latency period for thyroid cancers is 4-5 years.

The FGI made it possible to conduct a detailed analysis of the incidence of thyroid cancers in adolescents and young adults and of the development of these cancers after exposure in childhood.

3.1 BELARUS: ANALYSES

Data for Belarus come from the national cancer registry (BCR). French and Ukrainian histopathologists collaborated on blinded testing to verify these thyroid cancers and thus validated the diagnoses internationally [Franc et al., 2003]. Information collected about diagnostic programs provided an inventory of the number of ultrasound instruments installed from 1990 onward, which increased capacity to diagnose thyroid gland nodules. This better detection affected the increased incidence observed in Belarus over the study period, but its impact is difficult to quantify.
The most contaminated regions are Brest, Gomel and Mogilev, and the control regions Vitebsk, Minsk, Minsk City and Grodno [5].

The incidence of thyroid cancers increased continuously since 1990 in those older than 15 years at diagnosis in almost all regions studied (figures 6 and 7).

Figure 6: Annual incidence rate of thyroid cancers, standardized for age, in men older than 15 years at diagnosis, in Belarus

Figure 7: Annual incidence rate of thyroid cancers, standardized for age, in women older than 15 years at diagnosis, in Belarus
This study [5] revealed regional disparities and illustrated the different rates of increase according to contamination level. The increase, already quite clear in women by 1992-1996, was visible for men as well 15 years after the accident (1997-2001).

The fact that this increase was not specific to the strongly contaminated regions leaves some doubt about the contribution of ionizing radiation to the higher incidence. Nonetheless, as thyroid cancer is recorded according to place of residence at diagnosis, it is possible that some increases, such as that in Minsk City, are linked to population migration from contaminated areas towards less contaminated areas, including the capital. The increase may also be due in part to the progressive installation of ultrasound equipment that began in 1990. Nonetheless, it must be borne in mind that this type of cancer can be radiation-induced and is detectable 4-5 years after exposure, unlike other types of cancers which have much longer latency periods.

Belarus scientists also examined the risk of those exposed very young. The incidence of thyroid cancers among those aged 15-29 years at diagnosis has risen continually since the accident. This large rise, which began in 1998 in this age group, reflects the contribution of children younger than 10 years in 1986. On the other hand, the incidence rates for children born after the accident, are returning to those of the pre-accident period (see the rates for children aged 0-14 years at diagnosis in 2000: figure 8). Globally, figure 8 illustrates an increase in thyroid cancers according to age at exposure: children exposed at early ages continue to show an excess of thyroid cancers as young adults.
Figure 8: Annual thyroid cancer incidence in Belarus (age at diagnosis), 1980-2001.

3.2 UKRAINE: ANALYSES

Incidence rates for thyroid cancers also increased significantly from 1990 in Ukraine, particularly in women in the most contaminated regions — Kiev, Zhytomyr, and Chernihiv [2]. This increase may be explained by both exposure to ionizing radiation and the obvious improvement in diagnostic procedures (figure 9).

Figure 9: Annual incidence rate of thyroid cancers, standardized for age, per 100,000 persons, among adolescents and adults in Kiev, Zhytomyr, and Chernihiv, 1980-1999

The following figure (figure 10) shows an excess of thyroid cancers among adolescents and adults in the regions most contaminated by iodine 131, compared with only slightly contaminated regions. The mean iodine 131 deposit increased between GR1 to GR3 (contamination levels: from less than 100 to more than 200 kBq per m²). There is an excess of thyroid cancers in the most contaminated regions, GR2 and GR3, and no difference between GR2 and GR3.
Figure 10: Annual incidence rate of thyroid cancer, standardized for age, in groups (GR) older than 15 years at diagnosis, in Ukraine

3.3 RUSSIA: ANALYSES

The thyroid cancer incidence rates in Russia were studied from 1982 through 1999 in the contaminated region of Bryansk and the not contaminated region of Orel [7]. After the accident, the standardized incidence rate increased in men and in women, regardless of region or age group (figures 11 and 12). We note nonetheless an augmentation in this rate for the 1992-1999 period, greater among women older than 15 years at diagnosis than among men. Moreover, the incidence of thyroid cancers began to increase in 1991, especially among those exposed during childhood or adolescence.
Figure 11: Annual incidence rate of thyroid cancer in men according to age at diagnosis, in Bryansk and Orel, 1982-1999

Figure 12: Annual incidence rate of thyroid cancer in women according to age at diagnosis, in Bryansk and Orel, 1982-1999

4. ANALYSIS OF THE INCIDENCE OF SOLID CANCERS

4.1 BELARUS: ANALYSES

Because the Belarus national cancer registry existed before 1986, it is possible to determine the incidence rates of rare diseases before the accident. Verification of registry data showed a high level of validity.

Comparisons of the incidence rates of various solid cancers in the populations of the contaminated region of Gomel and the control region of Grodno showed no differences between them, before or after the accident [8].
4.2 UKRAINE: ANALYSES

Retrospective validation of the Ukraine data was needed to ensure the quality of the post-accident information.

The incidence rate of solid cancers for the most contaminated oblasts of Zhytomyr [9] and Kiev increased slightly after the accident. According to the team of A.Ye. Prisyazhnyuk, these rates before and after Chernobyl differ almost not at all, except for a trend towards an increase among women (figure 13).

![Figure 13: Annual incidence rate of solid cancers in Zhytomyr and Kiev, 1980-1999](chart)

Figure 13: Annual incidence rate of solid cancers in Zhytomyr and Kiev, 1980-1999

Trends differ according to the type of cancer. Because solid tumors in adults require latency periods of 5-10 years, it is improbable that the increase in incidence rates in 1990-1994 is related to exposure to ionizing radiation.

The incidence of prostate cancer, not known to be related to radiation, increased after the accident — by 25.5% in 1990-1994 and by 57% in 1995-1999, compared with the first study period. It has since stabilized.
The number of breast cancer cases remained stable for 6-7 years after the accident, a duration that may correspond to its latency period. It then began to increase in 1992 (figure 14). This type of cancer can be induced even at low doses of radiation.

![Figure 14: Annual incidence rate of breast cancer in women, standardized for age, in Zhytomyr and Kiev, 1980-1999](image)

No pronounced increases were observed for other solid tumors, including those of the gastrointestinal system, the oral cavity, the ear, nose, and throat, or the respiratory system.

4.3 RUSSIA: ANALYSES

As in Ukraine, retrospective data validation was needed to ensure the quality of post-Chernobyl data.

Comparison of annual age-standardized incidence rates of solid cancers in the highly contaminated zones of Bryansk and the slightly contaminated zones of Kaluga showed no significant differences after the accident, except for breast cancer [10]. The incidence rate for breast cancer rose in the strongly contaminated zones compared with the control zones, regardless of age group (figure 15). These rates exceeded the mean rates in Russia.
Figure 15: Annual incidence rate of breast cancer in women in Bryansk and Kaluga, 1986-1998

This study showed that persons who developed cancer between 1991 and 1998 in the highly contaminated regions were exposed to lower doses less than healthy persons (who did not develop this cancer). Figure 16 shows the mean doses for the study cohort. The dots indicate the mean doses among the cancer cases diagnosed that year. Doses for cases differ from those for the rest of the cohort, but remain generally lower than those in the general population of the region. This makes it difficult to establish a causal link between dose and observed cases.
Figure 16: Means doses of the inhabitants of Bryansk and Kaluga aged 0-60 years at the beginning of exposure who developed cancer, 1991-1998

5. OBSERVATION OF THE EFFECTS OF EXPOSURES OF VERY YOUNG CHILDREN

5.1. EFFECTS ON INFANT MORTALITY

Data were collected from some contaminated regions and compared with those from control regions.
BELARUS: ANALYSES

Researchers paid special attention to data on infant mortality (glossary 4 and 5), and audits showed their high quality [11]. From 1981 to 2000, in the “contaminated” regions of Mogilev and Gomel and the control region of Vitebsk, the infant mortality rate fell continuously, regardless of contamination level (figure 17).

Figure 17: Infant mortality in the contaminated regions of Mogilev and Gomel and in the uncontaminated region of Vitebsk, Belarus, 1981-2000

The principal causes of death in children were congenital malformations, respiratory system diseases, or conditions associated with the perinatal period (figure 18). Similarly, according to G.A. Shishko’s team [11], early neonatal mortality, that is, during the first week of life, remained stable in Gomel, Mogilev and Vitebsk from 1980 through 2000. Neonatal mortality (that is, from birth to 30 days) in these regions was stable from 1980 through 1995 and then diminished through 2000. Trends for early neonatal and neonatal mortality were the same as those observed nationally.
Some conditions during the perinatal period (30.8%)  
Respiratory system diseases (15.8%)  
Infectious and parasitic diseases (9.7%)  
Neoplasms (0.7%)  
Congenital Malformations (29.0%)  

Figure 18: Principal causes of infant mortality in Belarus, 1988-2000

UKRAINE: ANALYSES

The infant mortality and stillbirths rate in the contaminated regions of Zhytomyr and Kiev and in the control region of Poltava tended to fall from 1980 through 2000, according to the team of N. Omelyanets [12]. The causes of infant mortality in the regions studied were respiratory system diseases, conditions related to the perinatal period, and congenital malformations. These results provide no clear response about the possible relation between the infant mortality index (per 1000 births) and exposure to ionizing radiation.

RUSSIA: ANALYSES

In the highly contaminated oblast of Bryansk and the slightly contaminated oblast of Kaluga, infant mortality rates showed no variations that could be associated with the level of cesium 137 contamination (figure 19) [13]. Researchers found downward trends in infant mortality in the highly contaminated regions from 1982 through 1998.

Figure 19: Infant mortality assessed at different periods in Russia
5.2. EFFECTS ON INFANT MORBIDITY

BELARUS: ANALYSES

Infant morbidity (glossary 6) increased continuously from 1981 through 1997/2000, from a mean of 75 per 1000 births in 1981 to 250 per 1000 births in 2000, in the contaminated regions of Mogilev and Gomel as in the control region of Vitebsk (figure 20) [112].

![Graph showing infant morbidity in Belarus, 1980-2000](image)

Figure 20: Neonatal morbidity, per 1000 births, all causes, in Mogilev, Gomel and Vitebsk (Belarus), 1981-2000

The leading causes of neonatal morbidity throughout the study period, regardless of region, were intrauterine hypoxia, neonatal asphyxia, congenital disorders and respiratory distress syndrome.

UKRAINE: ANALYSES

The Chernobyl accident led to a general increase in infant morbidity in almost all the regions studied, contaminated or not: health of newborns and children deteriorated [12]. Diseases of the respiratory system, some conditions related to the perinatal period, and diseases of the nervous system and of the sense organs were the leading causes of infant morbidity.

RUSSIA: ANALYSES

Infant morbidity in newborns — either the highly exposed children of Bryansk or the slightly exposed children of Kaluga — increased from 1987 through 1997 and was due principally to respiratory diseases [13]. Thyroid doses of iodine 131 were estimated for each child. To avoid regional specificities, an internal control was established: children in the highly and slightly contaminated regions were subdivided into two groups according to exposure. Despite this distinction, the gamma measurements did not differ between these groups of newborns.

In conclusion, there was no clear showing of any effect associated with ionizing radiation.
5.3 CONGENITAL MALFORMATIONS AND IN UTERO EFFECTS

5.3.1. CONGENITAL MALFORMATIONS IN BELARUS

Researchers studied the frequency of 9 congenital malformations as well as the head circumference of newborns in 4 regions of Belarus from 1983 through 1999. The contaminated regions were Gomel and Mogilev and the control regions Vitebsk and Minsk [14].

The following congenital malformations were observed: anencephaly (total or partial absence of a brain), spina bifida (malformations of the vertebral column), malformations of the lips and palate, polydactylies (hereditary anomalies characterized by the existence of extra fingers), limb reductions, atresia of the esophagus or anus, and Down syndrome (trisomy 21).

The Belarus national registry served as the basis of this study. An increase in the frequency of congenital disorders has been observed since 1987 in these regions, regardless of their level of contamination (figure 21).

![Figure 21: Prevalence at birth of congenital disorders in the highly contaminated regions of Gomel and Mogilev and the slightly contaminated regions of Vitebsk and Minsk](image)

A study according to type of malformation indicates that malformations of the neural tube, anencephaly and spina bifida have all increased in frequency since the accident in the control regions rather than the contaminated regions, although they do not exceed the frequency of anencephaly in neighboring countries, such as France, between 1992 and 1999. Malformations of the lip or palate increased moderately in the regions studied and are similar to those in other regions; an peak was observed in the regions contaminated in 1987.

The frequency of polydactylies rose significantly in the first years after the accident, regardless of study region.

The prevalence of upper limb reductions and defects increased slightly in both study regions. The frequency of rectal and esophageal atresia was generally lower in contaminated than control regions. Researchers identified a significant increase in the frequency of Down syndrome in January 1997 and are now analyzing it. Generally, results in contaminated regions were lower than those in uncontaminated regions.
These results do not rule out the possibility that exposure to radiation affected the frequency of congenital malformations, but they showed that other factors are also involved, including increased diagnostic awareness and screening for these diseases since the accident. G. Lazjuk and his team were unable to identify any effect among the children of exposed populations born after the accident.

The head circumference of newborns whose mothers lived in contaminated regions was an average of 1.1 cm smaller than that of infants whose mothers lived in uncontaminated regions.

5.3.2. POSSIBLE EFFECTS ON THE BRAIN OF CHILDREN EXPOSED IN UTERO IN UKRAINE

Children born between April 26 1986 and February 26 1987 to mothers evacuated from Pripyat, a contaminated city, and to mothers living in Kiev, the control region, underwent a variety of tests [15]. The children's individual doses were reconstructed. Doses to the fetal thyroid and brain were greater in the exposed children—as much as 15 times greater for the thyroid.

The WISC test (Wechsler Intelligence Scale for Children) is a clinical instrument designed for the individual measurement of intelligence in children aged 6-16 years. The children exposed in utero had a lower verbal intellectual quotient (IQ) (glossary 8, 9) than the children in the control groups, while their performance IQ (glossary 10) was essentially identical (figures 23 and 24).

![Figure 22: Verbal IQ](image1)

![Figure 23: Performance IQ](image2)

The gap between the performance IQ and the verbal IQ, called the IQ discrepancy, was higher in exposed children. When this gap is greater than 25 points, brain damage is considered to be correlated with radiation doses to the fetus. This discrepancy appeared in 13.6% of the evacuated children, compared with 4.4% in the control group.

Emotional and behavioral disorders measured by Achenbach's test were more frequent in children exposed in utero than in control children for somatic conditions, depression and anxiety, social problems, attention disorders, and so on. Similarly the exposed children had more mental and
neuropsychiatric disorders than the control groups. Nonetheless, school performance was similar in the two groups.

Mothers' verbal IQs did not differ in the two groups after adjustment for their mental health. Accordingly the lower verbal IQ in the exposed children cannot be explained by lower maternal IQ. On the other hand the evacuated women were under severe stress and had more mental problems associated with depression and anxiety, evacuation, and lack of information and medical care than the control women.

There was no relation between the children's poor test results and the doses they had received and no relation between the doses in utero and either neuropsychiatric disorders or diverse health problems. On the other hand, mothers' mental health deterioration was associated with children's lower performance IQ and neuropsychiatric disorders.

6. DIETARY AND NUTRITIONAL PRACTICES IN UKRAINE

The study of nutritional practices included the creation of a database of dietary habits and nutritional status to better understand some of the cofactors likely to affect the health of the exposed populations [16]. Adults (18 years and older) and children (1-6 years) in regions with different contamination levels were questioned 14 years after the accident.

Researchers could not identify any associations between the nutritional situation of a region and its contamination level. On the one hand, no information on this topic was available for the pre-Chernobyl period, and on the other, regional situations did not differ by contamination level.

Protein and carbohydrate intake were both too high, according to international guidelines, and may thus promote the development of diseases such as kidney failure or diabetes. There were also two problems requiring a more immediate public health intervention:

- obesity in women: 20% of the women were obese, and this obesity was correlated with overall excess food intake, without any nutritional imbalance
- anemia in children: there was an elevated prevalence of moderate anemia: 34% of the children aged 1-6 years had anemia and the percentage was higher in those younger than 4 years (44.3%) than in those 4-6 years (25%).
7. ISSUE OF DOSE RECONSTRUCTION IN LIQUIDATORS

After the accident, emergency action was taken to control radioactive emissions, remove reactor debris, build its "sarcophagus", clear the ground, decontaminate, etc. Numerous "liquidators" including plant employees, firefighters, members of the armed forces, and civilians participated in these activities from 1986 through 1990. Although the liquidators received the highest doses, they rarely wore dosimeters. A review of relevant files estimates their number at approximately 600 000. At the end of 1990, all persons who had worked at any point since the accident within a 30-k radius of the plant were called "liquidators". Their medical follow-up was difficult, in part because they came from different countries (Russian, Ukrainian, Estonian, etc) and are now dispersed through the republics that succeeded the USSR.

Dose reconstruction was needed because neither dosimetric practices nor the data for liquidators were clear for the period from the accident to the end of clean-up.

The principal work on this subject included [17]:

- Critical review of bibliographic data on this subject
  257 scientific publications from the national and international literature covering the period 1986-2000 were collected in a database. Access to these documents is therefore now possible.

- Investigations related to liquidator dosimetry during 1986-1987 to reconstruct dosimetric practices.
  Different types of investigations were conducted: studies of the Chernobyl clean-up period, different liquidator cohorts, dosimetry services, methods and instruments, legislation, evaluation of information quality, etc.

- Acquisition of more than 6000 teeth for individual dosimetry to validate the data. This collection provides a highly precise and solid basis for retrospective analyses, since tooth enamel allows us to determine the liquidators' external exposure to gamma radiation. This project was designed in May 1997 in Ukraine, and the teeth are stored in a biological sample bank. In all, 3875 liquidators donated 6197 teeth.
8. DECISION SUPPORT AND CURRENT RESULTS IN DATABASE FORM

A database was created to make it possible to access information about contaminated villages in Belarus. The data, collected from 1993 through 2001, cover approximately 15,000 inhabitants of villages with contamination levels ranging from 2.5-27.5 Ci/km² (9.25-10 Bq-101.75-10 Bq), and approximately 65,000 food samples.

This database, named the RHP database after the "radiologic and health passports" it made it possible to put together, contains assessments of various indicators for 96 settlements. It provides statistical, economic and radiologic information about the contaminated villages of Belarus and the tools needed to make them useful to policy-makers [18].

Another common database, HEDAC (Health Effects Database After Chernobyl) [19], also covers the accident's health effects. It brings together the basic data from the studies cited above and validated by the researchers directly involved. It allows researchers to exchange these data. The results from each team were synthesized by summarizing the notable findings from the individual reports. All of these reports are accessible on the HEDAC database.

External parties may request authorization from the research team for access to HEDAC. Policy-makers and the public can also accede to the syntheses of the final reports.

The RHP and HEDAC databases should make it easier to understand the evolution of health indicators in various regions and generate hypotheses for future research, in the field of radiation and of other environmental factors. It should also allow different partners to collaborate in the future, especially by maintaining and developing high-quality cancer registries in Belarus and in some regions of Russia and Ukraine.

9. DISCUSSION

Ingestion of iodine 131 in the weeks after the accident caused substantial thyroid irradiation. A very sharp increase in thyroid cancers in children was observed in these three countries. As of today, descriptive studies have not shown a clear excess of other solid tumors or of congenital malformations in the most contaminated regions. The interpretation of leukemia incidence by period, by sex, and by comparison of exposed and unexposed regions does not allow us to conclude that it has increased markedly in the post-accident period. Because leukemia is a rare disease, especially for those younger than 40 years, a slightly increase related to the accident at Chernobyl cannot be ruled out, but it has not been demonstrated, despite the size of the study population.

Moreover, findings from an isolated result published in a study of one or two regions cannot be generalized to all of the contaminated territories. These first results from the FGI cannot be
appropriately interpreted without taking into account all the other factors that may affect these incidence rates.

Although a negative effect from exposure to ionizing radiation cannot be ruled out, it is possible that the increased incidence rates observed are due in part to a greater interest since the accident in some diseases considered to be radiation-sensitive. This interest could well lead to an increase in diagnoses and improve the quality of screening, especially in children and in the highly contaminated regions.

At the time of the accident, the population underwent internal contamination and external irradiation. Radioisotopes of iodine, cesium, strontium and plutonium were the most dangerous. Retrospective contamination estimates were possible because of cesium 137, which has a half-life of 30 years, unlike iodine 131, which decreases rapidly (half-life of 8 days) and disappeared from the environment in several months. The exact doses received during the first year after the accident are thus difficult to estimate.

Reconstruction of exposure levels to study the risk of thyroid cancer led researchers to determine mean levels of iodine 131 deposits: this estimate served as a basis for the comparative analyses. On the other hand, it was collected from information about the level of stable iodine in soil, and this level may differ from that of the human body because individuals’ work and diet may influence their iodine levels.

Factors such as socioeconomic conditions (migration, lifestyle changes, etc), and genetic predispositions can also influence cancer development. A preliminary study assessed the psychological disorders of the liquidators in Ukraine [20]. The results compared with national data are interesting, but the work is not yet sufficiently advanced.

Despite the accomplishments of recent years, efforts must continue to study leukemia and the different types of solid cancers.

A second group of results concerns health problems related to exposures at an early age: infant mortality and morbidity, in utero exposure and potential brain effects, preconceptional and in utero exposure and congenital malformations. These studies provide information about the effects of ionizing radiation on fetuses and very young children.

Nutritional status in Ukraine was studied to obtain better information about some cofactors that may influence the global health status of an exposed population. Some biological indicators were also measured for specific subgroups. The principal results showed that 20% of the women are obese and 34% of children aged 1-6 years anemic. The establishment of the radiologic-hygiene passports involved many partners and represents an important experiment in regional risk management in Belarus.

Support must continue for registries to follow the time trends of diseases, especially as some solid tumors do not express a radiation-induced excess until after latency periods longer than 20 years.
10. CONCLUSION

International collaboration as part of the FGI health project enabled the construction of a large database. Although all of the data were not analyzed during the collaboration period (1997-2004), they remain available for other research studying radiation-induced risk or more generally the health follow-up of populations concerned by the accident at Chernobyl.

Results acquired during the FGI collaboration are available to policy-makers, physicians and the scientific community. The detailed final reports are available at the website http://www.fgi.icc.gov.ua.

The "Chernobyl Center" should also organize communication for the general public.

Finally, it must be stressed that the syntheses drafted, the data collected and the articles published demanded substantial efforts from all partners. The FGI health project represents 7 years of joint work; the continuation of that work now depends on the participants directly involved in Belarus, Russia and Ukraine. The success of their work also depends on the interest of the international community in the continuation of these studies.
FINAL REPORT AND PUBLICATIONS

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BASIC GLOSSARY

(1) Incidence: number of new cases of a disease in a given population, during a given period.

(2) Incidence rate: number of new cases of a disease in a given population during a year (usually expressed as the number of cases per 100 000 persons).

(3) Standardization: method used to eliminate effects due to differences, of age or sex for example, between the exposed group and the unexposed group before comparing the incidence rate observed for both groups.

(4) Infant mortality: number of children who die during their first year of life (usually expressed per 1000 births).

(5) Infant mortality rate: number of children who die during their first year of life, who were born with a weight of at least 1000 g and at a term of at least 22 weeks, per 1000 births in a given population.

(6) Infant morbidity: number of children with a disease during their first year of life. It is calculated as the ratio of the number of sick children younger than 1 year divided by the total number of children younger than 1 year.

(7) Control group: group of healthy undiseased persons selected for characteristics similar to those of the exposed group.

(8) IQ: Intelligence quotient: quantitative index of intellectual development measured with intelligence tests.

(9) Verbal IQ: ability to express oneself and understand what is said, including the consideration of information, its understanding, vocabulary, etc.

(10) Performance IQ: this involves “practical intelligence” or “action intelligence”. This IQ refers principally to spatial relations, drawing and organizing images, and assembling objects.