Incidence Rates of Tuberculosis among Children and Adolescents Living in Areas Most Affected by the Chernobyl Disaster

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Background. The Chernobyl accident has attracted the attention of healthcare experts all over the world due to the unprecedented scale of damage the disaster inflicted upon human health. Objectives. To examine incidence rates of tuberculosis and patterns among children and adolescents living in areas most affected by the Chernobyl disaster between 2004 and 2014.

Methods. The tuberculosis incidence rate was calculated per 100,000 people. Incidence dynamics were traced for the period 2004 to 2014 and average rates were measured. Average incidence rates were calculated for different age groups, including 0–4 years, 5–9 years, 10–14 years, and 15–19 years, as well as the total value for all those between 0–19 years of age. Average incidence rates were estimated for tuberculosis, pulmonary tuberculosis and extrapulmonary tuberculosis. A comparative analysis of incidence rates of tuberculosis in areas more and less affected by the Chernobyl disaster was conducted. To avoid gender and age disparities among the population in the two different study areas, a method of direct standardization was applied.

Results. Tuberculosis incidence rates showed identical patterns among the population across all areas in this region. At the same time, the incidence rates of tuberculosis, pulmonary tuberculosis, and extrapulmonary tuberculosis were higher among children and adolescents living in the most affected areas in comparison to those living in less affected areas.

Conclusion. The results do not allow us to conclude whether radioactive pollution has a direct impact on incidence of tuberculosis among children and adolescents in the most radioactively contaminated areas. The author believes that the higher incidence rates of tuberculosis in the most affected areas are conditioned by a set of negative factors that have a pernicious influence on the general health of the population, and on the health of children and adolescents in the areas most affected by the Chernobyl disaster.

Competing Interests. The authors declare no competing financial interests.

Patient Consent. Obtained

Ethics Approval. This study was approved by the Ethics Committee of the National Research Practical Centre «Mother and Child» as part of the research project: "Development and Implementation of a Comprehensive System of Measures for Prevention of Tuberculosis among Children's Population in the Affected Areas." (State registration number 20143300, date of registration 01/12/2014)

Keywords. Chernobyl accident, affected areas, children, adolescents, tuberculosis

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(137Cs) with a 30-year half-life were the two radionuclides that delivered the highest radiation dose to the population as a result of their release into the atmosphere.8

The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) reported that “iodine-131 was the main contributor to the thyroid doses, received mainly via internal irradiation within a few weeks after the accident. In contrast, 137Cs was (and remained) the main contributor to the doses to organs and tissues other than the thyroid, due to either internal or external irradiation; these doses would continue to be received at low rates over several decades.”8

UNSCEAR rates the collective thyroid dose to the 98 million residents of the former Soviet Union at 1,600,000 man Gray (man Gy). At the country level, the collective thyroid dose was highest in Ukraine (960,000 man Gy distributed over 51 million people), however the average thyroid dose in Ukraine was about 3 times lower than in Belarus.8 At the regional level, the highest collective thyroid dose was to the population of the Gomel region (located in Belarus), where a collective thyroid dose of about 320,000 man Gy was distributed over a population of 1.6 million people, corresponding to an average thyroid dose of about 200 milligray (mGy).8

Compared to Russia and Ukraine, Belarus recorded the highest (rounded) dose to the population of the contaminated areas exposed to radiation as a result of the Chernobyl accident.8 The average thyroid dose was 1.5 times higher in Belarus (182 mGy) than in Ukraine (123 mGy), and 6.7 times higher than in Russia (27 mGy).8 The average effective dose to this population between 1986 and 2005 was 1.2 times higher in Belarus (12 millisievert (mSv)) than in Ukraine (10 mSv), and 1.7 times higher than in Russia (7 mSv).8 The collective thyroid dose to this population group was 1.2 times higher in Belarus (320,000 man Gy) than in Ukraine (260,000 man Gy) and 4.6 times higher than in Russia (70,000 man Gy).8

The average thyroid dose to children and teenagers was the highest in the Gomel region of Belarus and exceeded the rates recorded in other Belarusian regions, as well as in Russia and Ukraine.8 The average thyroid dose to pre-school children in the Gomel region was 475.8 mGy, 3.9 times higher than the average thyroid dose to pre-school children in the whole of Belarus (122 mGy) and 9.9 times higher than the average thyroid dose to pre-school children in all three countries combined (Belarus, Russia and Ukraine) (48 mGy).8 The average thyroid dose to school children in the Gomel region was 250.3 mGy, 4 times higher than the average thyroid dose to school children in the whole of Belarus (63 mGy) and 13.2 times higher than the average thyroid dose to school children of the three countries combined (19 mGy).8 The average thyroid dose to adolescents in the Gomel region was 145 mGy, 3.9 times higher than the average thyroid dose to adolescents in the whole of Belarus (37 mGy) and 11.2 times higher than the average thyroid dose to adolescents of the three countries combined (13 mGy).8

Most radionuclides released as a result of the Chernobyl disaster had disintegrated to lower levels by 2008. Currently, 137Cs remains the main contributor to the radiation dose.8 UNSCEAR reports 137Cs to be the main contributor to the dose to organs and tissues other than the thyroid, due to either internal or external irradiation, and contends that the afore-mentioned doses will continue at low rates over the next several decades.8

The total quantity of 137Cs deposited in the former Soviet Union as a result of the accident, including in areas of lesser deposition, was estimated to be approximately 40 PBq (petabecquerels), and apportioned as follows: 40% in Belarus; 35% in the Russian Federation; 24% in Ukraine; and less than 1% in other republics of the former Soviet Union. Regionally the highest estimate of 137Cs density is in the Gomel region at 154 kilobecquerels (kBq)/m2.8

The radioactive nuclides distributed by the Chernobyl accident in the environment had different characteristics as well as biological effects. Radioactive iodine led to

**Abbreviations**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Unit</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>kBq</td>
<td>Kilobecquerels</td>
<td>UNSCEAR</td>
</tr>
<tr>
<td>man Gy</td>
<td>Man gray</td>
<td>United Nations Scientific Committee on the Effects of Atomic Radiation</td>
</tr>
<tr>
<td>mGy</td>
<td>Milligray</td>
<td>WHO</td>
</tr>
<tr>
<td>mSv</td>
<td>Millisievert</td>
<td>Caesium-137</td>
</tr>
<tr>
<td>PBq</td>
<td>Petabecquerels</td>
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substantial health effects as a result of the Chernobyl disaster. It has been recognized by the World Health Organization (WHO) that the development of thyroid pathology and subsequent thyroid cancer development among the population affected by the Chernobyl disaster is a result of irradiation with radioactive iodine-131. From 1992 to 2002 in Belarus, Russia and Ukraine, more than 4000 cases of thyroid cancer were diagnosed among those who were children and adolescents (0–18 years) at the time of the accident.\textsuperscript{9}

The impact of the Chernobyl accident on the health of the Belarus population has attracted the attention of healthcare experts all over the world due to the unprecedented scale of damage the Chernobyl disaster inflicted upon human health.\textsuperscript{10,11} Many people in Belarus have been exposed to long-term small-dose radiation that inflicted grave consequences on the health of the population, especially children.\textsuperscript{12} Aleynikova et al. reported an increased incidence of all types of chronic leukemia and non-Hodgkin lymphoma in the Gomel and Mogilev areas.\textsuperscript{13} An increase in breast cancer was observed in women from areas in the Gomel region where the deposits of $^{137}$Cs exceeded 555 kBq/m$^2$ from 1990–2003. Breast cancer rates increased by 1.2% among the monitored women of the Vitebsk region and by 5.7% in the Gomel areas with deposits of $^{137}$Cs of more than 185 kBq/m$^2$; while in the areas with deposits of $^{137}$Cs exceeding 555 kBq/m$^2$ there was a breast cancer rate increase of 32.7%. The risk of breast cancer increased by 25% in women who live in contaminated areas. In addition, women aged 55-59 years constitute the highest risk group in the most contaminated areas of the Gomel region, while in the Vitebsk region, the highest risk group consists of women aged 70-74 years (94.9 ± 6.8 per 100,000 female population). An increase of non-oncological diseases among the population in the contaminated areas such as autoimmune thyroiditis, cataracts and circulatory system diseases was also noted. The increase in disease incidence was linked with radiation exposure combined with a set of factors—environmental, anthropogenic, psychological, social and economic disturbances, the Soviet Union collapse and deterioration of the quality of life. The study also contends that exposure to ionizing radiation might have aggravated and ignited all of these negative factors.\textsuperscript{13}

In addition, after the Chernobyl disaster, epidemiological surveys revealed a rise in the rate of tuberculosis in the radioactively polluted areas. The tuberculosis incidence rate in 1985 was 75.8 cases per 100,000 people and the most destructive forms of tuberculosis accounted for 17.2% of all cases, while in 1996 the tuberculosis incidence rate was 84.0 cases per 100,000 people and the most destructive forms of tuberculosis accounted for 41.7% of all cases.\textsuperscript{14}

From 1991 to 1995, the tuberculosis incidence rates in Belarus increased by 42.5%, while the rates of mortality caused by tuberculosis increased by 28.6%.\textsuperscript{15-17} The incidence rates for pulmonary tuberculosis with bacterioexcretion increased from 12.8 cases per 100,000 people in 1991 to 17.9 cases in 1995.\textsuperscript{16} In the Gomel region the tuberculosis incidence rates increased from 50.4 cases per 100,000 people in 1993 to 60.5 cases per 100,000 people in 1996,\textsuperscript{15-18} and tuberculosis incidence rates in the radioactively polluted areas exceeded the national average by 43%.\textsuperscript{17} The spread of tuberculosis across the radioactively polluted areas has been linked with a comprehensive set of negative factors, such as cuts in the number of preventive X-ray examinations of the population, rising levels of migration outflow from the regions with high tuberculosis rates, worsening socioeconomic situation, poverty, micro-epidemics of tuberculosis among alcohol and drug addicts, and fear of X-rays.\textsuperscript{15,18,19}

Studies conducted between 1983 and 1996 found higher rates of drug resistant tuberculosis, tuberculosis mortality rates and tuberculosis relapse rates in areas more affected by the Chernobyl disaster compared to areas less affected by the disaster.\textsuperscript{20-22}

Tuberculosis incidence rates among children and adolescents from different areas of Belarus did not vary much before the Chernobyl disaster. After the disaster, tuberculosis incidence rates among children and adolescents increased in the Gomel region, reaching 2.7 times the national average in 1994, and tripling between 1985 to 1996, increasing from 4.1 cases per 100,000 people in 1985 to 12.8 cases per 100,000 people in 1996.\textsuperscript{15-18,23-26} Prior to this, tuberculosis incidence rates had decreased by 7.6% among children in the monitored areas of the Gomel region from 1981–1985. From 1991–1995, tuberculosis incidence rates among children in these areas increased by 45.8%.\textsuperscript{25,26}

Currently, the incidence rates of tuberculosis in Belarus are significantly lower than those in other post-Soviet countries. However, according to the Global Tuberculosis Report 2015 of the WHO, Belarus was listed among 27 other countries with a high multidrug-resistant tuberculosis burden.\textsuperscript{27} Incidence rates of tuberculosis among children and adolescents are closely linked to the spread of tuberculosis among adults. Considering the
prevalence of aggressive infections among the adult population, a study of tuberculosis incidence rates among children and adolescents is useful. Research on tuberculosis incidence rates among children and adolescents is also important for forecasting the future of the tuberculosis epidemic and developing appropriate prevention measures.

The objective of this study was to examine tuberculosis incidence rates and patterns among children and adolescents living in areas most affected by the Chernobyl disaster, analyzing data from 2004 to 2014.

**Methods**

Radioactively contaminated areas were legally defined by the Republic of Belarus on May 26, 2012 in a statue (No. 385-3) titled “The legal regime for territories affected by radioactive contamination as a result of the disaster at the Chernobyl Nuclear Power Station.” The statute defined radioactive contamination zones as the areas across Belarus with a density of soil contamination of $^{137}$Cs, strontium-90, or plutonium-238, -239, -240, equaling or exceeding 37, 5.55, and 0.37 kBq/m$^2$ (1.0, 0.15, 0.01 Ci/km$^2$), respectively. In addition, according to this legislation, the average annual effective radiation dose to the population in these territories may exceed 1 mSv (over the natural and technogenic background level). As a result of this law, radioactively polluted areas have been divided into the following zones:

1. **Evacuation zone (Exclusion zone)**—the area around the Chernobyl nuclear station. The population in this area was evacuated in 1986 (30-km radius of land whose inhabitants were resettled due to soil contamination density of strontium-90 exceeding 111 kBq/m$^2$ (3 Ci/km$^2$) and the level of plutonium-238, -239, and -240 exceeded 3.7 kBq/m$^2$ (0.1 Ci/km$^2$)).

2. **Zone of primarily resettlement**—area with soil contamination density of $^{137}$Cs exceeding 1480 kBq/m$^2$ (40 Ci/km$^2$) or soil contamination density of strontium-90 or plutonium-238, -239, and -240 exceeding 111 and 3.7 kBq/m$^2$ (3 and 0.1 Ci/km$^2$), respectively.

3. **Zone of subsequent resettlement**—area with soil contamination density of $^{137}$Cs between 555-1480 kBq/m$^2$ (15-40 Ci/km$^2$), soil contamination density of strontium-90 between 74-111 kBq/m$^2$ (2.3 Ci/km$^2$), or soil contamination density of plutonium-238, -239, and -240 between 1.85-3.7 kBq/m$^2$ (0.05-0.1 Ci/km$^2$). The average annual effective radiation dose to the population in these territories may exceed 5 mSv (over the level of natural and technogenic background). The zone also includes areas with lower soil contamination density for these radionuclides, but where the average annual effective radiation dose to the population exceeded 5 mSv.

4. **Zone with the right of resettlement**—area with soil contamination density of $^{137}$Cs between 185-555 kBq/m$^2$ (5-15 Ci/km$^2$), strontium-90 between 18.5-74 kBq/m$^2$ (0.5-2 Ci/km$^2$), or plutonium-238, -239, and -240 between 0.74-1.85 kBq/m$^2$ (0.02-0.05 Ci/km$^2$). The annual effective radiation dose to the population in those territories may exceed 1 mSv (over the level of natural and technogenic background). The zone also includes areas with lower soil contamination density of these radionuclides, but where the average annual effective radiation dose to the population exceeded 1 mSv.

5. **Zone of residence with periodic radiation monitoring**—area with a soil contamination density of $^{137}$Cs between 37-185 kBq/m$^2$ (1-5 Ci/km$^2$), strontium-90 between 5.55-18.5 kBq/m$^2$ (0.15-0.5 Ci/km$^2$), or plutonium-238, -239, and -240 between 0.37-0.74 kBq/m$^2$ (0.01-0.02 Ci/km$^2$). The average annual effective radiation dose to the population in these territories may exceed 1 mSv (over the level of natural and technogenic background).

In Belarus, the Gomel region occupies the largest territory, accounting for a fifth of the country’s land. This region was the most affected by the Chernobyl disaster. Table 1 gives the number of settlements located in the radioactively polluted territories in the Gomel region between 2004 and 2014, according to the data of the Central Statistics Committee of the Gomel region. Table 2 shows the total population living in the settlements in the Gomel region situated in the radioactively polluted areas between 2004 and 2014 according to the data of the Central Statistics Committee of the Gomel region.

For the present study, a database was developed where all primary cases of tuberculosis among children and adolescents in the Gomel region during 2004–2014 were recorded. The Gomel region accounts for 25.2% of all registered tuberculosis cases among children and adolescents in the Republic of Belarus. The following criteria were considered in the analysis: tuberculosis verified by the bacteriological method and/or radiological method, patient age between 0–19 years, and permanent residence of patient in the Gomel region. Patient consent was obtained. This study was approved by the Ethics Committee of the National Research Practical Centre «Mother and Child» as part of the research project: “Development and Implementation of a Comprehensive System of Measures for Prevention of Tuberculosis among Children’s Population in the
Affected Areas.” (State registration number 20143300, date of registration 01/12/2014).

All children and adolescents diagnosed with tuberculosis and recorded in this database were then divided into two groups. The first group included children and adolescents living in the areas most affected by the Chernobyl disaster. The second group included children and adolescents living in less affected areas of the Gomel region.

The overall characteristics of the areas most affected by the Chernobyl disaster in the Gomel region are presented in Table 3.

The list of areas most affected by the Chernobyl disaster was made in

### Table 1 — Number of Settlements Located in the Radioactively Polluted Territories in the Gomel Region Between 2004-2014

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Number of Settlements Located in Radioactive Contamination Zones</th>
<th>Total number of settlements with resident population</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>1,481</td>
<td>1,462</td>
</tr>
<tr>
<td>2005</td>
<td>1,427</td>
<td>1,414</td>
</tr>
<tr>
<td>2006</td>
<td>1,426</td>
<td>1,414</td>
</tr>
<tr>
<td>2007</td>
<td>1,426</td>
<td>1,410</td>
</tr>
<tr>
<td>2008</td>
<td>1,404</td>
<td>1,396</td>
</tr>
<tr>
<td>2009</td>
<td>1,404</td>
<td>1,391</td>
</tr>
<tr>
<td>2010</td>
<td>1,313</td>
<td>1,299</td>
</tr>
<tr>
<td>2011</td>
<td>1,309</td>
<td>1,289</td>
</tr>
<tr>
<td>2012</td>
<td>1,308</td>
<td>1,278</td>
</tr>
<tr>
<td>2013</td>
<td>1,308</td>
<td>1,277</td>
</tr>
<tr>
<td>2014</td>
<td>1,308</td>
<td>1,277</td>
</tr>
</tbody>
</table>

### Table 2 — Total Population Living in Settlements in the Gomel Region Situated in Radioactively Polluted Areas Between 2004–2014

<table>
<thead>
<tr>
<th>Year</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>1,142,201</td>
</tr>
<tr>
<td>2005</td>
<td>1,023,944</td>
</tr>
<tr>
<td>2006</td>
<td>1,017,956</td>
</tr>
<tr>
<td>2007</td>
<td>1,013,215</td>
</tr>
<tr>
<td>2008</td>
<td>1,012,087</td>
</tr>
<tr>
<td>2009</td>
<td>1,011,955</td>
</tr>
<tr>
<td>2010</td>
<td>1,000,627</td>
</tr>
<tr>
<td>2011</td>
<td>879,335</td>
</tr>
<tr>
<td>2012</td>
<td>882,655</td>
</tr>
<tr>
<td>2013</td>
<td>886,375</td>
</tr>
<tr>
<td>2014</td>
<td>889,374</td>
</tr>
</tbody>
</table>

Data adapted from statistics compiled by the Central Statistics Committee of the Gomel region.
compliance with the decree of the Council of Ministers of the Republic of Belarus of June 9, 2000, No 845, and includes the following 13 areas in the Gomel region: Bragin, Buda-Koshelevo, Vetka, Dobrush, Elsk, Kalinkovichi, Korma, Lelchitsy, Narovlia, Rahachou, Rechitsa, Khoinkiki and Chechersk. The location of these areas is shown in Figure 1.

The list of less affected areas is comprised of 8 territories in the Gomel region that were not mentioned in the list of the areas most affected by the Chernobyl disaster, including the region’s major city Gomel. These areas include Gomel city, Zhitkovichy, Zhlobin, Loyev, Mozyr, Octyabr, Petrikov, and Svetlogorsk.

Calculations were made for the intensive indicators of tuberculosis incidence rate per 100,000 people in the present study. The incidence dynamics were traced during the period from 2004 to 2014 and the average rates were measured. Average tuberculosis incidence rates were calculated for different age groups, including 0–4 years, 5–9 years, 10–14 years, and 15–19 years, as well as the total value for all those between 0–19 years. Average incidence rates were estimated for tuberculosis, pulmonary tuberculosis and extrapulmonary tuberculosis (for the period from 2004 to 2014). A comparative analysis of tuberculosis incidence rates in the areas most affected by the Chernobyl disaster and less affected areas of the Gomel region was conducted.

To avoid gender and age disparities among the population in the two different study areas, a method of direct standardization was applied. Data on age composition of the population of Belarus for the period 2004–2014 was used as a standard for calculating incidence rates. The official census data of the National Statistical Committee of the Republic of Belarus.
for the population inhabiting the areas of the Gomel region and the Republic of Belarus in general were used for calculating indicators of tuberculosis incidence rates.

**Results**

From 2004–2014, tuberculosis incidence rates decreased among the population aged between 0–19 years living in the Gomel region. As depicted in Figure 2, a decrease in tuberculosis incidence rates was recorded among the population inhabiting both study areas. Nevertheless, tuberculosis incidence rates in the population in the areas most affected by the Chernobyl disaster decreased at a swifter pace. The tuberculosis incidence rates in less affected areas decreased from 5.66 cases per 100,000 people in 2004 to 5.22 cases in 2014, a decrease of 7.8%. Simultaneously, the tuberculosis incidence rates among the population in the most affected areas decreased by 2.5 times—from 13.44 cases to 5.38 cases per 100,000 people.

The observed decrease in the tuberculosis incidence rates among children and adolescents in the Gomel region from 2004–2014 may be explained by the reduced number of tuberculosis inspections conducted in Belarus. The annual screening by the Mantoux tuberculin skin test that had been compulsory for all children was cancelled in 2011. Moreover, the decrease in tuberculosis incidence rates in the Gomel region is in line with the general tendency of declining tuberculosis incidence rates currently observed throughout the world.

The average rate of tuberculosis incidence among children and adolescents aged 0–19 years for the period 2004–2014 was calculated. The average rate of tuberculosis incidence in the areas most affected by the disaster was determined to be 7.32 cases per 100,000 people, which is 1.5 times higher than the average rate of tuberculosis incidence in less affected areas (4.86 cases per 100,000 people).

To exclude differences in the age of the population in the two different study areas, standard rates of tuberculosis incidence in the population in the two different areas in the Gomel region between 2004 and 2014 were determined. A method of direct standardization was applied to determine standard rates. The composition of the Belarusian population aged between 0–19 years between 2004 and 2014 was taken as a standard. The results are shown in Figure 3.

As seen in Figure 3, after tuberculosis incidence rates were standardized, the disparity between the rates in the areas most affected by the disaster and less affected areas became more conspicuous. Before the standardization, the tuberculosis incidence in the most affected areas was 1.5 times higher than the tuberculosis incidence in less affected areas (7.32 vs 4.86 cases per 100,000 people), and after standardization the rate was 1.7 times higher (8.24 vs 4.79 cases per 100,000 people).

Therefore, supposing the population aged between 0–19 years in the two study areas of the Gomel region was age-homogeneous, tuberculosis incidence rates in the most affected areas would be 1.7 times higher than in less affected areas. Thus, the differences in the age structure of the population had an impact on tuberculosis incidence rates among these two different populations. These estimates may indicate higher prevalence rates of tuberculosis infection among children and adolescents in the areas most affected by the Chernobyl disaster.

A study on tuberculosis incidence rates was carried out focusing on
localization of the pathological process in the human body, i.e., pulmonary tuberculosis vs extrapulmonary tuberculosis. The average pulmonary tuberculosis incidence rates among the population aged between 0–19 years during 2004–2014 were determined. The pulmonary tuberculosis incidence rate in the most affected areas was 5.20 cases per 100,000 people, which is 1.4 times higher than the pulmonary tuberculosis incidence rates in less affected areas (3.75 cases per 100,000 people).

Similar to the results on tuberculosis incidence, standardized rates of pulmonary tuberculosis incidence in the population aged between 0–19 years in the two study areas were determined. The outcomes of those calculations are shown in Figure 4.

As seen in Figure 4, after the pulmonary tuberculosis incidence rates were standardized by age, the disparity between the rates became more conspicuous. Before standardization, the pulmonary tuberculosis incidence in the most affected areas was 1.4 times higher than in less affected areas (5.20 vs. 3.75 cases per 100,000 people), and after standardization the rate was 2.9 times higher (6.13 vs. 2.11 cases per 100,000 people). Therefore, if we assume that the population in the two study areas in the Gomel region had a homogeneous age structure, the pulmonary tuberculosis incidence rates in the most affected areas would be 2.9 times higher than in less affected areas. Thus, the differences in age structure of the population had an effect on pulmonary tuberculosis incidence rates among the population in the two different study areas in the Gomel region. Again, these estimates may point to the higher incidence rates of pulmonary tuberculosis among children and adolescents in the most affected areas.
The average extrapulmonary tuberculosis incidence rate among the population aged between 0–19 years during 2004–2014 was determined. The average extrapulmonary tuberculosis incidence rate in the most affected areas was 2.12 cases per 100,000 people, which is 1.9 times higher than the rate in less affected areas (1.11 cases per 100,000 people). Extrapulmonary tuberculosis is characterized by a more severe clinical course. The disease is less effectively treated than pulmonary tuberculosis and there are more cases of failed treatment. The higher incidence of extrapulmonary tuberculosis among children and adolescents in the most affected areas indirectly indicates a more severe tuberculosis clinical course among the population in these areas. Similarly, standardized rates for extrapulmonary tuberculosis in the population aged between 0–19 years in the two different study areas were determined. The results are shown in Figure 5.

As demonstrated by the results, standardization of rates did not impact the incidence ratio for extrapulmonary tuberculosis in the two different study areas. Before the rates were standardized, the incidence rate of extrapulmonary tuberculosis in the most affected areas was 1.9 times higher than the rate of extrapulmonary tuberculosis in less affected areas (2.12 vs 1.11 cases per 100,000 people), and after standardization the same rate was found, i.e. a 1.9-fold difference (2.11 vs 1.11 cases per 100,000 people). Thus, differences in the age structure of the population did not affect the extrapulmonary tuberculosis incidence rates in the population of the two different areas in the Gomel region. As previously noted, these estimates suggest the presence of higher prevalence rates of extrapulmonary tuberculosis in children and adolescents in the most affected areas. The average incidence rates in different age groups (0–4; 5–9; 10–14; 15–19 years) in the two study areas for the period 2004–2014 were determined. The results of the calculations are shown in Figure 6.

It has been found that tuberculosis incidence rates increase with age, which is a general characteristic of tuberculosis epidemiology. The present study found this trend to be a long-standing pattern for both of the study areas. The lowest tuberculosis rates were detected in the youngest age group (0–4 years). The tuberculosis incidence rates for the group aged between 0–4 years in the most affected areas were 15.1% lower than in the less affected areas (1.8 cases per 100,000 people in the most affected areas vs 2.12 cases in less affected areas). For the group aged between 5–9 years, tuberculosis incidence rates were higher than for the group aged between 0–4 years. The tuberculosis incidence rates for the group aged between 5–9 years were 1.8 times higher in the most affected areas compared to the less affected areas (4.44 cases vs 2.51 cases per 100,000 people, respectively). For the group aged between 10–14 years, tuberculosis incidence rates were relatively identical for the two study areas (3.62 cases vs 3.67 cases per 100,000 people, respectively). The low tuberculosis incidence rates for the groups aged between 0–4, 5–9 and 10–14 years may be partially explained by insufficient tuberculosis diagnostics among children in these age groups.

The highest incidence of tuberculosis
was detected in the oldest age group (between 15–19 years). The tuberculosis incidence was 2.1 times higher in the most affected areas than in less affected areas (19.53 cases vs 9.36 cases per 100,000 people, respectively). The tuberculosis incidence rates observed for the group aged between 15–19 years may be a more realistic reflection of the general epidemic situation of tuberculosis among the population, because in Belarus, adolescents at this age are examined for tuberculosis more thoroughly. The population aged between 15–19 years is screened for tuberculosis by the following two methods: skin testing (Mantoux tuberculin skin test or the Diaskin test) and by the radiological method.

The present study revealed a higher tuberculosis incidence among adolescents living in the areas most affected by the Chernobyl disaster than from less affected areas, as well as different tendencies in incidence rates of pulmonary and extrapulmonary tuberculosis among various age groups of the population.

The incidence rates of pulmonary tuberculosis in the population of the two study areas had identical patterns and were marked by a wide range of fluctuations—from 0.36 cases to 17.4 cases per 100,000 people. While rates were low among children, rates were high among adolescents. This pattern is shown in Figure 7.

The lowest pulmonary tuberculosis incidence rates were detected in children in the youngest age group (0–4 years) living in the most affected areas, 2.9 times lower than in less affected areas (0.36 cases vs 1.06 cases per 100,000 people, respectively). The incidence of pulmonary tuberculosis in children aged between 5–9 years was 2.91 times lower than in less affected areas (0.36 cases vs 1.06 cases per 100,000 people, respectively). The incidence of pulmonary tuberculosis in children aged between 10–14 years was 2.51 times higher in the most affected areas than in less affected areas (1.48 cases vs 0.57 cases per 100,000 people, respectively). The incidence of pulmonary tuberculosis in children aged between 15–19 years was 2.1 times higher in the most affected areas than in less affected areas (17.4 cases vs 8.32 cases per 100,000 people, respectively).

A dramatically different tendency was revealed in the analysis of incidence rates of extrapulmonary tuberculosis among different age groups of the population. These rates showed only minor fluctuations compared to pulmonary tuberculosis. The highest incidence was estimated at 2.96 cases per 100,000 people, while the lowest rate was 1.04 cases per 100,000 people. The incidence for all age groups was higher among the population in the most affected areas compared to less affected areas. This pattern is shown in Figure 8.

The incidence rates of extrapulmonary tuberculosis for the youngest age group (0–4 years) living in the most affected areas was 5.83 times higher than in less affected areas (0.36 cases vs 0.20 cases per 100,000 people, respectively). The incidence of extrapulmonary tuberculosis in children aged between 5–9 years was 5.0 times higher in the most affected areas than in less affected areas (0.36 cases vs 0.07 cases per 100,000 people, respectively). The incidence of extrapulmonary tuberculosis in children aged between 10–14 years was 3.7 times higher in the most affected areas than in less affected areas (0.36 cases vs 0.10 cases per 100,000 people, respectively). The incidence of extrapulmonary tuberculosis in children aged between 15–19 years was 3.67 times higher in the most affected areas than in less affected areas (2.51 cases vs 0.72 cases per 100,000 people, respectively).

For instance, younger children are selectively examined for tuberculosis and only by the Mantoux tuberculin skin test.
The incidence rates of extrapulmonary tuberculosis among children aged 5–9 years in the most affected areas were 2.2 times higher than for the same age group in less affected areas (2.96 cases vs 1.35 cases per 100,000 people, respectively). The incidence rates of extrapulmonary tuberculosis for children aged between 10–14 years was 1.9 times higher in the most affected areas than in less affected areas (1.97 cases vs 1.05 cases per 100,000 people, respectively). The incidence rates of extrapulmonary tuberculosis for children aged between 15–19 years were 2.13 times higher in the most affected areas than in less affected areas.

After standardization, the disparity between the tuberculosis incidence rates in the two study areas increased. The same pattern was noted for pulmonary tuberculosis incidence. The results demonstrated that the higher prevalence of tuberculosis and pulmonary tuberculosis in the areas most affected by the Chernobyl disaster is not conditioned by the age structure of the population in those areas. This clearly points to a higher prevalence of tuberculosis infection among the population in the areas most affected by the disaster.

In the course of the comparative analysis of the tuberculosis incidence across age groups, a clear pattern emerged showing that the incidence of pulmonary tuberculosis increased with age. The highest rates of pulmonary tuberculosis were detected in the oldest age group of adolescents,
Conclusion

The results of the present study do not allow us to conclude whether radioactive pollution has a direct impact on tuberculosis incidence among children and adolescents in the most radioactively contaminated areas of the Gomel region. However, the author believes that the higher tuberculosis incidence rates in the most affected areas of the Gomel region are conditioned by a set of negative factors that have a pernicious influence on the health of the population in these areas.

The results of the present study demonstrate the need for further research on the health of children and adolescents in the areas of the Gomel region most affected by the Chernobyl disaster. The incidence of tuberculosis in children and adolescents as well as in adults should be studied in these areas. A comparative study of the immune system of children and adolescents with latent and active tuberculosis who live in different areas in the Gomel region is another potential area for further research, with an evaluation of individual absorbed doses. Modern laboratory, micro–biological, molecular genetic and immunologic technologies should be applied in the course of such research.

The Expert Group on Health presented a report at the United Nations Chernobyl Forum titled "Health Effects of the Chernobyl Accident and Special Health Care Programmes", and researchers emphasized the urgency and importance of conducting monitored surveys on infectious diseases and the immune condition of children in the affected and non-affected territories.31

The results of the present study demonstrate the need for enhanced tuberculosis prevention among children and adolescents living in the areas most affected by the Chernobyl disaster. The data acquired in the course of the present research can be further applied to the planning and implementation of tuberculosis prevention campaigns among the population in the areas most affected by the Chernobyl disaster.

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Figure 8 — Average incidence rates of extrapulmonary tuberculosis across age groups in the Gomel region for the period 2004–2014
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