Hemoblastosis morbidity in employees occupationally exposed to long-term "low"-dose ionizing radiation

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Abstract. There has been analyzed hemoblastosis and leukemia morbidity in Siberian Group of Chemical Enterprises (SGCE) employees occupationally exposed to long-term low-level ionizing radiation. It has been found that hemoblastosis and leukemia morbidity in SGCE males is significantly higher as compared to the national and regional standards. The incidence rate in males is observed at the expense of non-radiation support production workers. No increase in leukemia morbidity risk depending on cumulative external radiation dose in the range up to 1 Sv has been found.

Key Words: hemoblastosis, leukemia, ionizing radiation, "low" doses.

Introduction

Malignant tumors morbidity is one of the most immediate problems in modern medicine [1, 2]. Hemoblastosis (HBL) is the most rampant kind of malignant tumors and on the 6th-8th places in Russia [1, 2]. HBL occurrence depends on genetic and environmental factors such as ionizing and ultraviolet radiation, chemical agents and some kinds of viruses. Carcinogenic properties of ionizing radiation (IR) were discovered after X-rays had been. In the following years there was collected a great number of clinical materials: tumors and HBL, particularly those that were medically irradiated [3, 4].

Thus, leucosis occurrence was found due to radiation, excluding chronic lymphatic leukemia (CLL) [5-7].

A long-term study of the survivors of Hiroshima and Nagasaki bombardment is the main epidemiological one on the basis of which carcinogenic risk indices have been evaluated. Basing upon mortality study of atomic-bombsurvivors during 1950-1990 the value of leukemia relative risk made up 4,62/1 Sv; the value of absolute risk made up 2,61/10 000 person-years-Sv. Relative risk of malignant tumors, excluding leukemia, made up 0,4/1 Sv; the value of absolute risk made up 0,6/10 000 person-years-Sv [7].

Japanese cities A-bom bing was an acute accident; and the results of many studies show that chronic exposure can cause smaller values of risk as compared with acute exposure. Over the last years it was found out that even low-level chronic exposure can cause higher progression in HBL and leukemia.

A study done by a team of scientists from the United States, Great Britain and Canada shows that there has been revealed a high level of leukemia morbidity (excluding CLL) among the nuclear industry employees exposed to radiation in the range of 0-400 mSv. Leukemia relative risk was evaluated as 2,18 per 1 Sv; however high risk of solid cancers was not found [6, 8, 9].

Of great importance are data on leukemia morbidity among riverside residents exposed to radiation because of massive releases of waste into the Techa River (South Urals) from the Mayak radiochemical facility [10, 11]. Over the period 1950-1994 out of 16 900 exposed individuals there was revealed 50 cases of leukemia. The level of leukemia morbidity is significantly higher in exposed population in comparison with the control group: 10,01 and 5,98 cases for 100 000 person-years respectively (M.M. Kosenko at al., 1996).
Thus, nowadays evaluation of long-term effects of "low"-dose ionizing radiation is of current interest taking into account possible variants in the development of atomic energy and referral of atomic industry enterprises personnel as well as population living in radio-contaminated areas to contact with technogenic sources of radiation.

**Materials and methods**

The object of the study is the town of Seversk residents, a part of which is SGCE workers occupationally exposed to long-term "low"-dose IR.

The purpose of the study was to analyze HBL and leukemia incidence in SGCE employees in order to estimate possible dependence of HBL morbidity on long-term "low"-dose IR.

The level, structure and dynamic of HBL morbidity was analyzed on the basis of the "Oncological Diseases" register of Regional Medico-Dosimetric database.

HBL morbidity was studied in 597 adult Seversk residents, 391 of which are non-SGCE workers (150 males and 241 females) and 206 SGCE workers (34.5% of all adult Seversk residents with hemoblastosis).

The main production workers, who are in direct contact with IR sources, make up 52.6% of the whole SGCE personnel. The proportion of the main and support productions males and females makes up 3.9:1 and 2.2:1 respectively. 46.4% of the main production workers has external $\gamma$-radiation dose. 86.22% of the whole SGCE workers has cumulative external radiation dose within the range from 0.03 to 200 mSv and 10.34% – from 201 to 500 mSv. Totally, it makes up 96.56% of workers exposed to external radiation.

The study covered the period 1953-2003. The first HBL cases were registered in Seversk in 1955.

Morbidity rates were calculated by using generally accepted statistical methods [13]. The general data were taken from the national (Russian national statistics) and regional (statistics for a regional centre – Tomsk city) standards.

Morbidity rates were calculated separately for males and females.

The data obtained show a factual level of morbidity in the individuals under study. Standardized relative risks (SRR) for hemoblastosis and leukemia incidence were calculated as well.

**The results of research and discussion**

The database contains information on 597 HBL cases among adult Seversk residents. The number of HBL cases among SGCE personnel makes up 206 individuals. HBL and leukemia morbidity was studied in 199 cases. The study excluded 7 cases of hemoblastosis in those SGCE workers who had previously been employed at Mayak PA (Ozyorsk, Chelyabinsk region).

Data on HBL morbidity among SGCE employees are presented in Table 1.

Table 1 show that the most frequent Nosological categories were found to be leukemia, NHL, Hodgkin’s disease and multiple myeloma, 42.7%, 38.2%, 10.6 and 8.5 respectively.
During the period under study the 'rough incidence' of HBL morbidity among SGCE males made up 19.6% (the 95% confidence interval: 16.4-23.2) that is significantly higher when compared with the regional standard.

Age-adjusted HBL incidence rate was found to be in males aged 45-49 and 50-54, with 95% confidence. HBL morbidity in individuals aged 20-24 is significantly lower when compared with the regional standard. A small number of HBL incidences up to 25 y.o. is explained by rigid requirements to health state when employing workers at SGCE main production factories.

HBL incidence in SGCE female workers (15.4; the 95% confidence interval: 11.9-19.7) has not any difference from females of Tomsk; but in females aged 20-24 and over 65 it is significantly lower when compared with the regional standard. However, SGCE females aged 50-54 have hemoblastosis more frequently than females of Tomsk.

It has been found that females have hemoblastosis less frequently than males in 1.3 times.

Standardized HBL incidence for SGCE males was found to be significantly higher as compared to the regional standard (21.5; the 95% confidence interval: 18.1-25.6). Standardized HBL incidence for SGCE females was found to have no difference from the group under control (14.4; the 95% confidence interval: 11.1-18.4).

Analysis of the SRR coefficients shows that HBL risk for SGCE males is significantly higher in comparison with the national and regional standards, 70% and 60% respectively. SGCE males have leukemia much more often (as well as leukemia excluding CLL) as compared to males of Russia and Tomsk, 1.6 and 1.4 times respectively (Table 2).

### Table 1

<table>
<thead>
<tr>
<th>Nosological category</th>
<th>Type of production</th>
<th>Reactor</th>
<th>Radiocchemical</th>
<th>Plutonium</th>
<th>Enrichment</th>
<th>Sublimate</th>
<th>Support</th>
<th>All productions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leukemia</td>
<td></td>
<td>5</td>
<td>2</td>
<td>11</td>
<td>4</td>
<td>4</td>
<td>59</td>
<td>85 (42.7%)</td>
</tr>
<tr>
<td>Leukemia excluding CLL</td>
<td></td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>1</td>
<td>2</td>
<td>24</td>
<td>35</td>
</tr>
<tr>
<td>Non-Hodgkin’s Lymphoma</td>
<td></td>
<td>6</td>
<td>10</td>
<td>9</td>
<td>10</td>
<td>7</td>
<td>34</td>
<td>76 (38.2%)</td>
</tr>
<tr>
<td>Hodgkin’s disease</td>
<td></td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>14</td>
<td>21 (10.6%)</td>
</tr>
<tr>
<td>Multiple myeloma</td>
<td></td>
<td>2</td>
<td>–</td>
<td>3</td>
<td>–</td>
<td>1</td>
<td>11</td>
<td>17 (8.5%)</td>
</tr>
<tr>
<td>Totally:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>199</td>
</tr>
</tbody>
</table>

### Table 2

<table>
<thead>
<tr>
<th>Nosological category</th>
<th>In comparison with the national standard</th>
<th>In comparison with the regional standard</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>males</td>
<td>females</td>
</tr>
<tr>
<td>Hemoblastosis</td>
<td>1.7 (1.4-2.0)*</td>
<td>1.3 (1.0-1.6)</td>
</tr>
<tr>
<td>Leukemia</td>
<td>1.6 (1.2-2.1)*</td>
<td>1.4 (0.9-1.9)</td>
</tr>
<tr>
<td>Leukemia excluding CLL</td>
<td>1.6 (1.1-2.2)*</td>
<td>1.4 (0.9-2.1)</td>
</tr>
</tbody>
</table>

Note:* – hereinafter referred to as statistically significant differences; the 95% confidence interval is added within parentheses.
The study was aimed to assess the risks for HBL morbidity among SGCE different productions workers (Tables 3, 4).

Table 3

<table>
<thead>
<tr>
<th>Type of production</th>
<th>males</th>
<th>females</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reactor</td>
<td>1,1 (0,6-1,8)</td>
<td>0,3 (0,0-1,7)</td>
</tr>
<tr>
<td>Radiochemical</td>
<td>1,1 (0,5-2,0)</td>
<td>1,2 (0,2-3,4)</td>
</tr>
<tr>
<td>Plutonium</td>
<td>1,4 (0,8-2,3)</td>
<td>1,7 (0,7-3,3)</td>
</tr>
<tr>
<td>Enrichment</td>
<td>1,0 (0,5-2,0)</td>
<td>1,7 (0,6-3,6)</td>
</tr>
<tr>
<td>Sublimate</td>
<td>1,5 (0,7-2,9)</td>
<td>1,7 (0,4-4,3)</td>
</tr>
<tr>
<td>Support</td>
<td>2,3 (1,8-2,8)*</td>
<td>2,4 (1,7-3,3)*</td>
</tr>
<tr>
<td>All productions</td>
<td>1,7 (1,4-2,0)*</td>
<td>1,3 (1,0-1,6)</td>
</tr>
</tbody>
</table>

Table 4

<table>
<thead>
<tr>
<th>Type of production</th>
<th>males</th>
<th>females</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reactor</td>
<td>1,0 (0,5-1,7)</td>
<td>0,2 (0,0-1,4)</td>
</tr>
<tr>
<td>Radiochemical</td>
<td>1,1 (0,5-2,0)</td>
<td>0,9 (0,2-2,8)</td>
</tr>
<tr>
<td>Plutonium</td>
<td>1,4 (0,8-2,2)</td>
<td>1,4 (0,6-2,7)</td>
</tr>
<tr>
<td>Enrichment</td>
<td>1,0 (0,4-1,9)</td>
<td>1,3 (0,5-2,9)</td>
</tr>
<tr>
<td>Sublimate</td>
<td>1,4 (0,6-2,7)</td>
<td>1,3 (0,4-3,4)</td>
</tr>
<tr>
<td>Support</td>
<td>2,0 (1,6-2,5)*</td>
<td>2,0 (1,4-2,7)*</td>
</tr>
<tr>
<td>All productions</td>
<td>1,6 (1,3-1,9)*</td>
<td>1,1 (0,8-1,4)</td>
</tr>
</tbody>
</table>

Analysis of SRR coefficients shows that HBL morbidity risk for the support productions males and females (who are not in direct contact with IR sources) is 2 times higher than those of the regional standard.

According to further analysis of the SRR coefficients for all types of leukemia incidence in SGCE workers, leukemia risk is found to be 2.7 times higher for the support production males and females as compared to the national standard. Standardized relative risk for HBL morbidity among SGCE males significantly differs from 1 not only for all types of leukemia as a whole, but also for leukemia excluding CLL.

SRR for leukemia incidence among SGCE male workers is significantly higher as compared to the regional standard. The excess leukemia risk made up 70%. SRR for leukemia incidence among the SGCE support production males and females is significantly higher than that of the regional standard, 2.2 and 2.3 times respectively.

Leukemia incidence is significantly higher for all SGCE productions male workers as compared to the national and regional standards; the increase in morbidity in males is due to the support production workers’ incidence. Leukemia incidence in female workers has not any difference from females of Russia and Tomsk. However, for the group of the support production female workers, when compared to the regional and national standards, there have been revealed a significant excess of leukemia morbidity risk.
When calculated SRRs for leukemia incidence among SGCE personnel exposed to different external radiation dose in the range up to 1 mSv (0,03-100 mSv, 101-200 mSv, 201-500 mSv, 501-1000 mSv) no excess leukemia risk when increasing radiation dose has been found.

Conclusions
1. Leukemia takes a leading position in the structure of HBL morbidity among SGCE personnel.
2. HBL incidence is significantly higher for SGCE male workers as compared to the national and regional standards. HBL incidence for SGCE female workers has not any difference from females of Russia and Tomsk.
3. There have been found a significant increase in SRR for HBL morbidity among males and female SGCE workers non-exposed to technogenic radiation at workplace (in comparison with the national and regional standards).
4. Leukemia incidence is significantly higher for all SGCE productions male workers as compared to the national and regional standards; the increase in morbidity in males is due to the support production workers' incidence. Leukemia incidence for female workers has not any difference from females of Russia and Tomsk.
5. No excess leukemia risk when increasing cumulative external radiation dose in the range up to 1 Sv has been found.

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Тезисы, как справочные материалы

Заболеваемость гемобластозами среди лиц, подвергавшихся долговременному профессиональному облучению в диапазоне "малых" доз

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В настоящей работе проводился анализ показателей заболеваемости гемобластозами (ГБЛ) и отдельно лейкозами (Л) персонала крупнейшего в мире комплекса предприятий атомной индустрии – Сибирского химического комбината (СХК), подвергавшегося долговременному профессиональному облучению низкой интенсивности. Изучалась структура ГБЛ, а также проводился расчёт стандартизированных относительных рисков (СОР) заболевания ГБЛ и отдельно лейкозами. Изучаемый период 1953-2003 гг. В качестве стандарта использовались национальный (данные общероссийской статистики) и региональный (данные областного центра – г. Томска) стандарты.

Число работников СХК больных ГБЛ составляет 199 человек (34,5% от численности больных ГБЛ среди взрослого населения г. Северска). В исследование не были включены 7 случаев заболевания ГБЛ, зарегистрированных у работников СХК, ранее работавших на ПО "Маяк".

Анализ коэффициентов СОР показывает, что для всего мужского персонала СХК риск заболеть ГБЛ достоверно выше в сравнении с национальным и региональным стандартом, соответственно на 70% и 60%. Мужчины СХК достоверно чаще заболевали и лейкозами (в том числе Л за исключением хронического лимфолейкоза – ХЛЛ) по сравнению с мужчинами РФ и г. Томска в 1,6 и 1,4 раза соответственно.

Анализ коэффициентов СОР заболевания ГБЛ персонала отдельных производств позволил установить, что значение данного показателя у персонала вспомогательного производства (деятельность на котором не связана с воздействием радиационного фактора) достоверно превышает в 2 раза таковое в г. Томске, как для мужчин, так и для женщин.

Дополнительный анализ коэффициентов СОР заболевания всеми формами лейкозов персонала СХК позволил установить, что риск заболеть лейкозами (в 2,7 раза) выше как для мужского, так и для женского персонала вспомогательного производства, по сравнению с населением РФ. СОР заболевания мужчин СХК достоверно отличается от единицы не только для суммы всех форм лейкозов, но и для заболеваемости лейкозами за исключением ХЛЛ. При этом избыточный риск составил 60%. Мужчины вспомогательного производства достоверно чаще (в 2,5 раза) заболевают лейкозами за исключением ХЛЛ, чем мужчины РФ.

В группе женского персонала СХК значение коэффициента СОР заболевания лейкозами за исключением ХЛЛ достоверно превышает национальный стандарт лишь в группе женщин-работниц вспомогательного производства (в 2,4 раза).

Рассчитанные нами значения коэффициентов СОР заболевания лейкозами для мужчин СХК, в целом также свидетельствуют о достоверном превышении этого
показателя по сравнению с региональным стандартом. Избыточный риск заболевания лейкозами составил 70%. Значение коэффициента СОР заболевания лейкозами мужского персонала вспомогательного производства достоверно превышает таковое для мужчин г. Томска в 2,2, для женщин – в 2,3 раза.

Заболеваемость лейкозами среди мужского персонала всех производств СХК выше, чем в РФ и г. Томске, при этом превышение заболеваемости у мужчин отмечается за счёт заболеваемости персонала вспомогательного производства. Заболеваемость лейкозами женского персонала СХК в целом не отличается от заболеваемости в РФ и г. Томске. Однако в группе женщин-работниц вспомогательного производства зарегистрировано достоверное превышение риска заболевания лейкозами по сравнению с национальным и региональным стандартами.

**Ключевые слова:** гемобластозы, лейкозы, ионизирующее излучение
Hemoblastosis Incidence in Persons Exposed to Long Term Occupational Radiation in Low Dose Range

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Abstract

This paper was aimed to analyze factors of hemoblastosis and leucosis incidence in personnel of Siberian Group of Chemical Enterprises (SGCE) with low doses of chronic occupational exposure. Structure of hemoblastosis was analyzed, and standardized relative risks (SRR) were calculated for hemoblastosis and leucosis incidence. Years of study were 1953-2003. The general data were from national (Russian national statistics) and regional (statistics for a regional centre – Tomsk city) standards.

199 workers of SGCE have hemoblastosis, which is 34.5% of all adult Seversk residents with hemoblastosis. The study excluded 7 cases of hemoblastosis in those SGCE workers who had previously been employed at Mayak PA.

Analysis of the SRR coefficients has shown that hemoblastosis risk for male workers of SGCE is significantly higher than national and regional standards by 70% and 60% respectively. Male SGCE workers had leucosis significantly more often (as well as single types of leucosis excluding chronic lymphocytic leukemia) compared to men of Russia and Tomsk by 1.6 and 1.4 times respectively.

According to SRR coefficients analysis for hemoblastosis incidence in workers of various types of production, in auxiliary production employees (where they do not deal with radiation) this number is two times significantly higher than that of Tomsk for both sexes.

According to further analysis of SRR coefficients of all types of leucosis in SGCE workers, leucosis risk is (2.7 times) higher for both sexes employed in auxiliary production compared to the general Russian population. SRR of the disease significantly differs from 1 not only for all types of leucosis as a whole, but also for single types of leucosis excluding chronic lymphocytic leukemia. At the same time, excess risk was 60%. Men of auxiliary production have leukemia significantly (2.5 times) more often than those of Russia, excluding chronic lymphocytic leukemia.

In the group of female workers SRR coefficient for leucosis incidence, excluding chronic lymphocytic leukemia, is significantly (2.4 times) greater than the national standard only for auxiliary production personnel.

The calculated SRR coefficients for leucosis incidence in male SGCE workers as a whole indicate significant increase of this number compared to the regional standard. The excess risk of developing leucosis was 70%. SRR coefficient of developing leucosis for male workers of auxiliary production is significantly greater than that for Tomsk male residents by 2.2 times, for females it is 2.3 times.

Leucosis incidence in male workers of all SGCE productions is greater than throughout Tomsk or Russia; the increased incidence in men is due to auxiliary production employees' incidence. Leucosis incidence in female workers is not any different from women in Tomsk or Russia. However, in the group of auxiliary production female workers there was revealed significantly

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increased risk of developing leucosis compared to the regional and national standards.

*KEY WORDS:* hemoblastosis, leucosis, ionizing radiation.