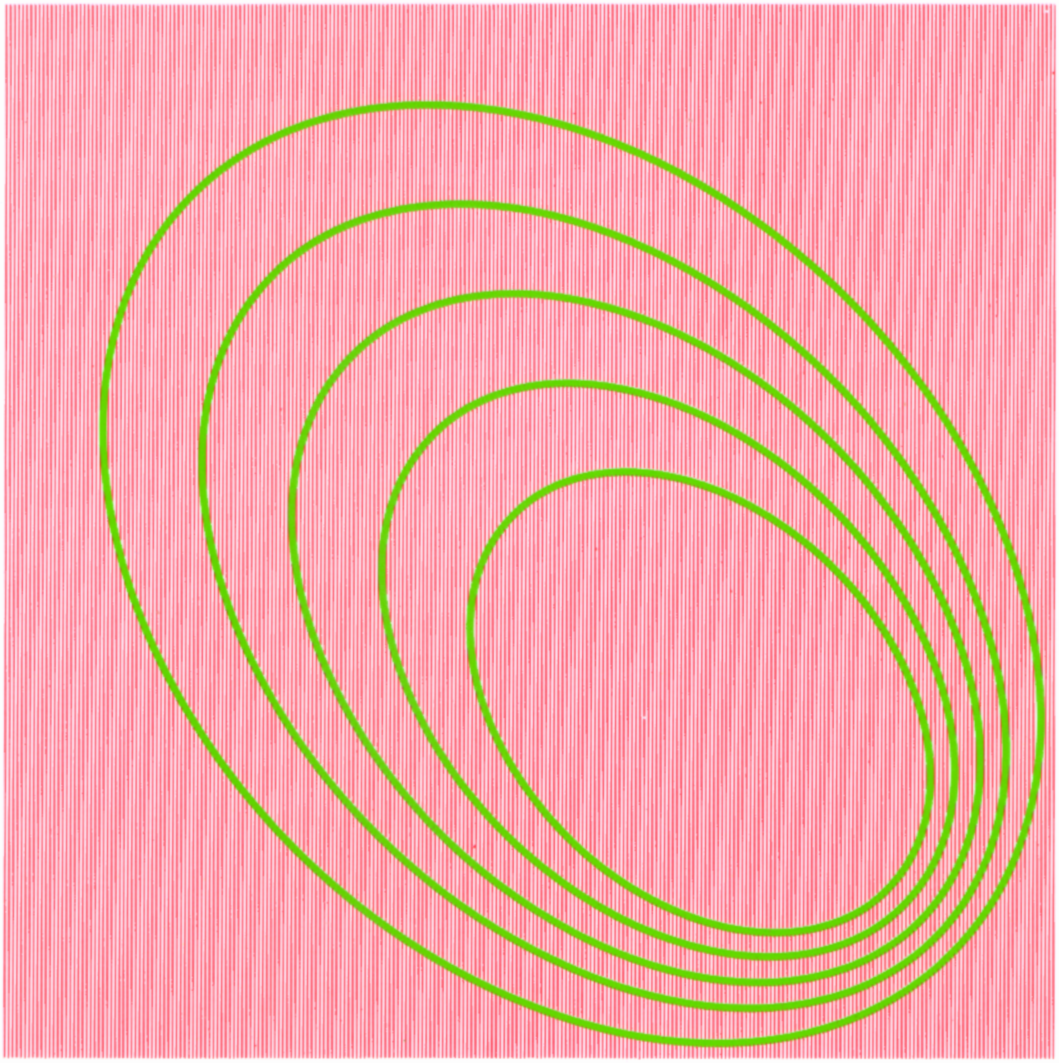
A Report on the 1995 Chernobyl Sasakawa Project Workshop

July 7–8, 1995

St. Petersburg



Sasakawa Memorial Health Foundation

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FOREWORD

This is the fourth report in the series. On the basis of a contract among three republics, five centers and the foundation, a project was launched in May 1991 to examine children under ten years of age at the time of the Chernobyl accident and living in the contaminated areas near the power plant. We believe that it was our duty to accurately convey the facts of this lamentable accident for the benefit of future generations. To this end, the persons in charge of examinations at the five centers gather once a year for a workshop to organize the collected data in a format suitable for detailed analyses, and the results of the workshop are presented at an annual symposium. The information contained in this report is the result of the fourth workshop.

The year 1995 marks the ninth anniversary of the Chernobyl accident and the passage of half a century since the atomic bombings of Hiroshima and Nagasaki. A century has passed, meanwhile, since Roentgen proved the existence of radiation, and the circumstances of human society have certainly improved during this period. The present project was conceived by Ryoichi Sasakawa, who passed away this year at the age of 96, as part of his great efforts to realize the ideal "The world is one family; all humankind are brothers and sisters." The present project is indeed a joint endeavor transcending differences of culture, history, language and socio-economic system, and its success in examining 130,000 children is undoubtedly due to a shared commitment among the people of Japan, Russia, Ukraine and Belarus to Mr. Sasakawa's ideal. More than anything else we are grateful for this commitment to and efforts toward the transcendence of international differences.

Mountain climbers say that the last one-fifth is half the climb. This means that we have now completed only half our mission. What remains to be done? Written in last year's report, the answer is our original purpose and the subject of worldwide interest: to elucidate "the effects of the Chernobyl accident on human health." The data of the 130,000 individuals must be used to achieve this purpose. Fortunately, the three republics have already begun discussions on this point, and a system of active cooperation is in the making. We are also strongly committed to the promotion of research that is scientific and at the same time beneficial to humanity.

The present report deals with the examination data that was collected from May 1991 to the end of 1994 and that is scheduled for discussion at the Fourth Chernobyl Sasakawa Medical Symposium in Gomel in November. It is true that an increase has been observed in thyroid cancer among children in the Gomel area. It remains to be seen, however, just how many of these cases are due to the Chernobyl accident.

Kenzo Kiikuni
Executive Managing Director
Sasakawa Memorial Health Foundation

September 1995

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Mogilev Regional Diagnostic Center

Kroupnik T.A., Dolbeshkin N.K., Voropai L.V., Rafeenko S.M., Moiseyenko N.V., Sharifov V.F., Zherko V.M., Koulikova N.V.

1. Introduction

The Chernobyl disaster caused an unfavorable medical situation in the Mogilev Oblast (Province). As of 1 January 1995, a territory 10,400 km^2 in area with a population of 181,500 including 45,700 children was exposed to ^{137}Cs contamination exceeding 1 Ci/km^2.

The health status of children and especially those residing in the exposed areas has deteriorated. More than 300 cases of thyroid cancer (including 20 children) and 30 cases of childhood leukemia have been registered in Mogilev Oblast since the Chernobyl accident. Other abnormalities in the endocrine, cardiovascular and hematopoietic systems and in metabolism are also observed frequently. It is therefore very important at the present time to achieve the early diagnosis of diseases in asymptomatic children.

Under these conditions, the Chernobyl Sasakawa long-term program for the medical examination of the health status of children renders inestimable assistance to health care authorities and to the population of the oblast. One of the goals of the project is to determine the extent of adverse effects of radioactive iodine and cesium isotopes on children's bodies. First of all this concerns "critical" organs: the thyroid and circulatory system as well as the associated risk for the induction of diseases.

The selection of groups, examination of children and collection of information is carried out based on specific methods with the help of special medical facilities donated by the Sasakawa Foundation (a mobile diagnostic laboratory installed in a Toyota minibus and a set of stationary equipment installed in the center).

The course of examination includes the following: (1) collection of disease history and biographical information; (2) anthropometric data; (3) registration of gamma radiation from the body of the child; (4) ultrasonography of the thyroid; (5) peripheral blood count; (6) determination of serum thyroid hormone levels and titers of thyroid autoantibodies; (7) determination of iodine and creatinine contents in the urine; and (8) examination by a pediatrician, hematologist and endocrinologist and by other specialists if required.

The information thus obtained is processed at the center and then entered into a database. Parents are informed in writing of the results of the examination. If abnormalities are found, the child in question is invited to visit the center for a comprehensive examination, professional consultation and recommendations for appropriate treatment.

The investigation is conducted within the framework of the state program for prophylactic medical examinations of the population exposed to the Chernobyl accident.

2. Materials and Methods

2.1 Study subjects

Screening was carried out among children who attend schools and kindergartens located in areas exposed to various radionuclide contamination levels. The subjects under study are children born between 26 April 1976 and 26 April 1986 and examined in the period from 15 May 1991 to 31 December 1994.

2.2 Measurement of whole body ^{137}Cs concentration

To determine the ^{137}Cs concentration in children's bodies, direct spectrometry of radionuclide activity was performed. This method is based on the registration of gamma radiation from the body. The Whole Body Counter 101 (WBC-101) manufactured by the Aloka Company (Japan) was used.

2.3 Thyroid examinations

Estimation of thyroid volume was performed with an arch-automatic ultrasonographic instrument (Aloka-SSD-520). Images of 11 cross sections of the thyroid were recorded on optic disc, then the total volume was calculated.

Diagnosis of thyroid disease was established on the basis of the following criteria of thyroid images: (1) position, (2) structure, (3) echogenity, (4) presence of nodules and cysts and (5) volume.

The serum free thyroxine (FT_4) and thyroid stimulating hormone (TSH) levels were determined with an Amerlite hormone analyzer using the immunometric technique based on enhanced luminescence. Studies were carried out by standardized protocol in parallels, i.e. with six standard solutions A, B, C, D, E and F. Titers of anti-thyroglobulin antibody (ATG) and anti-microsome antibody (AMC) were determined by the reaction of indirect hemagglutination (Fujirevio, Japan).

The children were divided into two groups according to thyroid volume: normal and goiter. The criterion for goiter is a thyroid volume exceeding the volume calculated by the following formula:

$$LIMIT = 1.7 \times 10^{0.013 \times age + 0.0028 \times height} \times (body\ weight)^{0.15},$$

where *age* is the age of the child in years at the time of the examination, *height* is the height of the child in cm and *body weight* is the weight of the child in kg. See Appendix B in *A Report on the 1993 Chernobyl Sasakawa Project Workshop*, 1993 for details.

Determination of iodine and creatinine content in the urine was carried out with a BRAN + LUBBE automatic Analyzer II.

2.4 Hematological studies

Hematological studies were conducted with K-1000 and NE-7000 hemoanalyzers manufactured by the Sysmex Company to determine the following eight parameters: (1) white blood cell count (WBC); (2) red blood cell count (RBC); (3) hemoglobin (Hb); (4) hematocrit (Ht); (5) mean corpuscular volume (MCV); (6) mean corpuscular hemoglobin (MCH); (7) mean corpuscular hemoglobin concentration (MCHC); and (8) platelet count (PLT).

The differential leukocyte count was determined using an Olympus BH-2 biological microscope and NE-7000 hemoanalyzer.

3. Results

3.1 Study subjects

From 15 May 1991 to 31 December 1994, 17,927 children (8,778 boys and 9,149 girls) were examined. These children, who ranged in age from 5 to 17 years, were residing in 12 rayons of the oblast: Slavgorodskii, Klimovichskii, Chausskii,

Table 1. Classification of study subjects by sex and place of residence.[a]

Place of residence	Boys	Girls	Total
Slavgorodskii	182 (7, 9, 12)	204 (7, 10, 12)	386 (7, 10, 12)
Klimovichskii	145 (9, 11, 13)	118 (9, 11, 12)	263 (9, 11, 12)
Chausskii	818 (8, 10, 12)	877 (8, 10, 12)	1695 (8, 10, 12)
Krichevskii	134 (6, 7, 8)	146 (6, 7, 8)	280 (6, 7, 8)
Bykhovskii	963 (9, 12, 14)	1046 (9, 11, 14)	2009 (9, 11, 14)
Mogilev City	4083 (9, 11, 13)	4297 (9, 11, 13)	8380 (9, 11, 13)
Mogilevskii	1210 (9, 11, 13)	1185 (9, 11, 13)	2395 (9, 11, 13)
Kostyukovichskii	247 (9, 12, 13)	282 (10, 12, 13)	529 (10, 12, 13)
Krasnopolskii	468 (9, 11, 13)	426 (9, 11, 13)	894 (9, 11, 13)
Cherikovskii	418 (9, 11, 13)	463 (9, 11, 12)	881 (9, 11, 12)
Klichevskii	61 (9, 10, 12)	54 (8, 10, 12)	115 (9, 10, 12)
Bobruiskii	14 (8, 10, 11)	21 (9, 11, 11)	35 (8, 11, 11)
Glusskii	35 (9, 11, 11)	30 (10, 11, 13)	65 (9, 11, 13)
Total	8778 (9, 11, 13)	9149 (9, 11, 13)	17 927 (9, 11, 13)

[a] Each triplet gives the 25th, 50th and 75th sample percentiles of age distribution at the time of examination.

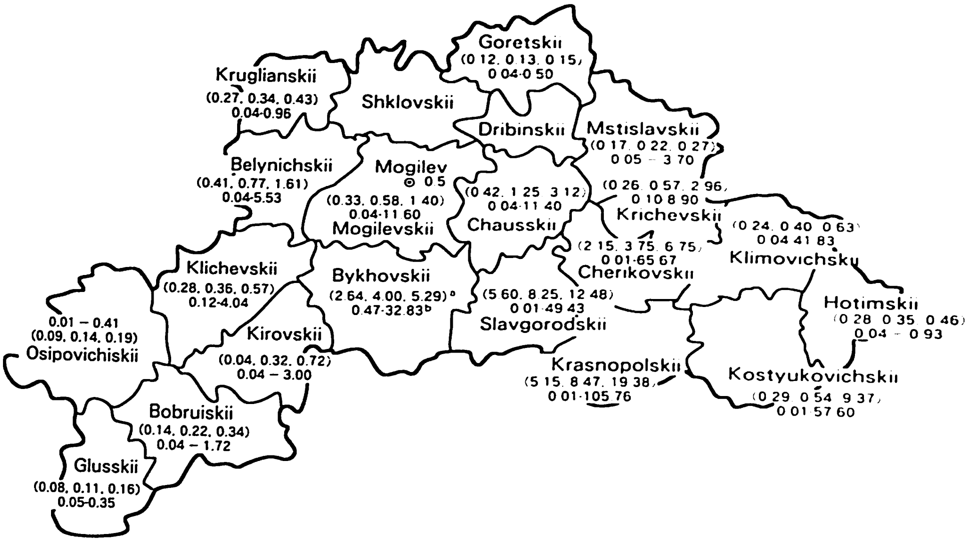

Figure 1. ^{137}Cs contamination levels (Ci/km^2) in the rayons of Mogilev Oblast as measured in 1992.

[a]The triplets give the 25th, 50th and 75th sample percentiles of contamination levels.

[b]Minimum and maximum levels of contamination.

Krichevskii, Bykhovskii, Mogilevskii, Kostyukovichskii, Krasnopolskii, Cherikovskii, Klichevskii, Bobruiskii, Glusskii Rayons and Mogilev City (Table 1). The triplets give the 25th, 50th and 75th sample percentiles of age distribution at the time of the examination in each group.

Figure 1 shows the rayons where ^{137}Cs contamination levels (Ci/km^2) were measured. The highest level of contamination was registered in Krasnopolskii Rayon (up to 105.8 Ci/km^2), Cherikovskii Rayon (up to 65.7 Ci/km^2) and Kostyukovichskii Rayon (up to 57.6 Ci/km^2). The triplet on the map of Mogilev Oblast indicates the 25th, 50th and 75th percentiles of the distribution of a ^{137}Cs contamination level in each rayon. The two numbers are the minimum and maximum contamination levels in each rayon.

3.2 Measurement of whole body ^{137}Cs concentration

Figure 2 shows the distribution of specific ^{137}Cs concentration in the bodies of children examined from 1 January 1994 to 31 December 1994 by sex and age. A total of 5,581 children were examined (2,745 boys and 2,836 girls), but the children with whole body ^{137}Cs count less than the detection limit, i.e. 540 Bq, were excluded from the figure. The number of boys and girls excluded in each age group was as follows (girls in parentheses): 8-year, 111(130); 9-year, 144(164); 10-year, 107(125); 11-year, 68(80); 12-year, 57(65); 13-year, 22(39); 14-year, 26(38); 15-year, 15(35); 16-year, 7(37); and 17-year, 3(8). No significant difference was observed in the ^{137}Cs content level of boys and girls. However, it should be noted that boys aged 15–17 years

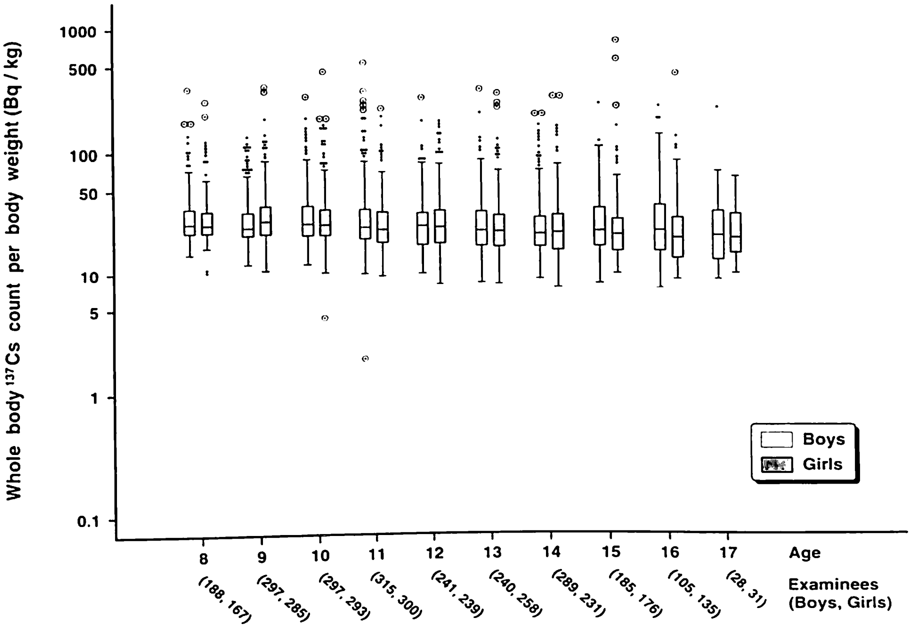

Figure 2. The box-and-whisker plots of whole body ^{137}Cs count per kg body weight by sex and age among children examined in 1994. The children with whole body ^{137}Cs count less than the detection limit (540 Bq) were excluded. The bottom and top ends of the box and the bar inside the box correspond to the 25th, 75th and 50th sample percentiles, respectively. The black dot and the double circle with black dot represent extreme values, called "outside" and "far out," respectively.

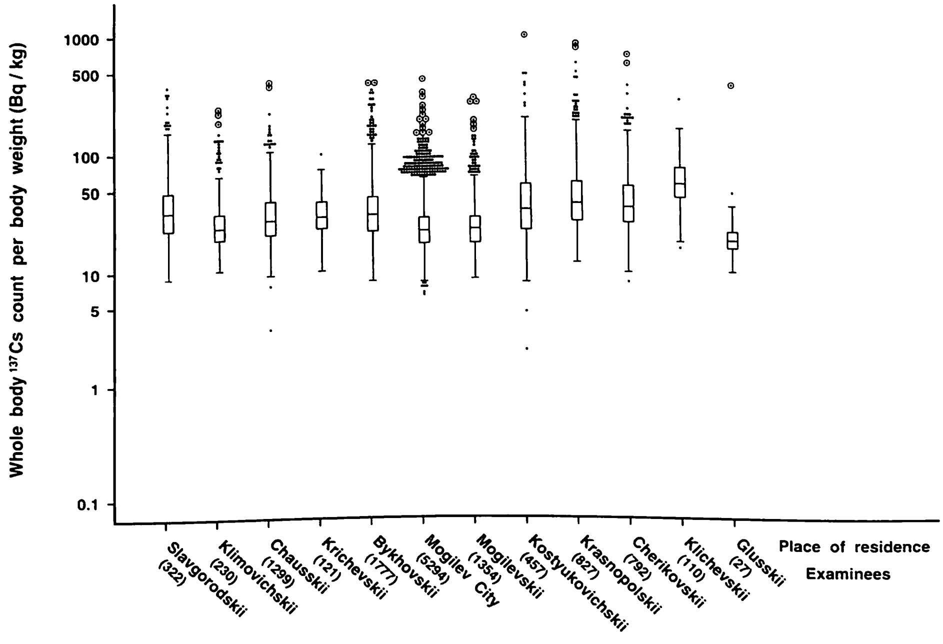

Figure 3. The box-and-whisker plots of whole body ^{137}Cs count per kg body weight by place of residence among children examined from 1991 to 1994. The children with whole body ^{137}Cs count less than the detection limit (540 Bq) were excluded. See Figure 2 for details.

accumulated ^{137}Cs more intensively than girls of the same age. The majority of ^{137}Cs specific activity values lay in the range of 10–80 Bq/kg.

Figure 3 shows the distribution of specific ^{137}Cs concentration in the bodies of children examined from 15 May 1991 to 31 December 1994 by place of residence. The number of children excluded from the figure having whole body ^{137}Cs count less than 540 Bq was as follows: 16 in Klimovichskii; 90 in Chausskii; 1 in Krichevskii; 25 in Bykhovskii Rayons; 866 in Mogilev City; 41 in Mogilevskii; 10 in Kostyukovichskii; 15 in Krasnopolskii; 81 in Cherikovskii; and 39 in Klichevskii Rayons. A high level of ^{137}Cs accumulation in the body was observed in Klichevskii (contamination level of the territory is in the range of 0.12 to 4.0 Ci/km^2), Krasnopolskii (0.01–105.8 Ci/km^2), Cherikovskii (0.01–65.7 Ci/km^2), Slavgorodskii (0.01–49.4 Ci/km^2), Kostyukovichskii (0.01–57.6 Ci/km^2) and Bykhovskii (0.47–32.8 Ci/km^2) Rayons.

3.3 Thyroid examinations

Figure 4 shows the relationship between thyroid volume and sex and age. The trend was towards an increase in thyroid volume with age in both boys and girls.

Figure 5 shows that the prevalence of goiter was higher in girls than in boys except in Klichevskii and Glusskii Rayons. The highest prevalence of goiter among boys and girls was found in the Chausskii Rayon.

Figures 6 and 7 show the relationship between the prevalence of goiter in children and ^{137}Cs contamination level in the place of current residence and ^{137}Cs contamination level in the place of residence at the time of the accident. No relationship was observed between the prevalence of goiter in boys and girls and the ^{137}Cs contamination level in the place in both figures. It is difficult to determine the relationship between the

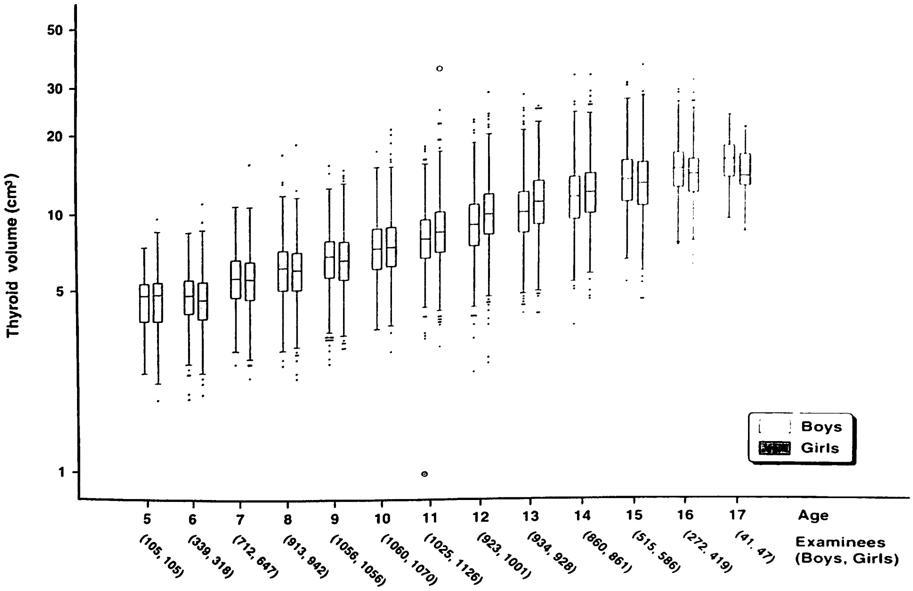

Figure 4. The box-and-whisker plots of thyroid volume by sex and age. See Figure 2 for details.

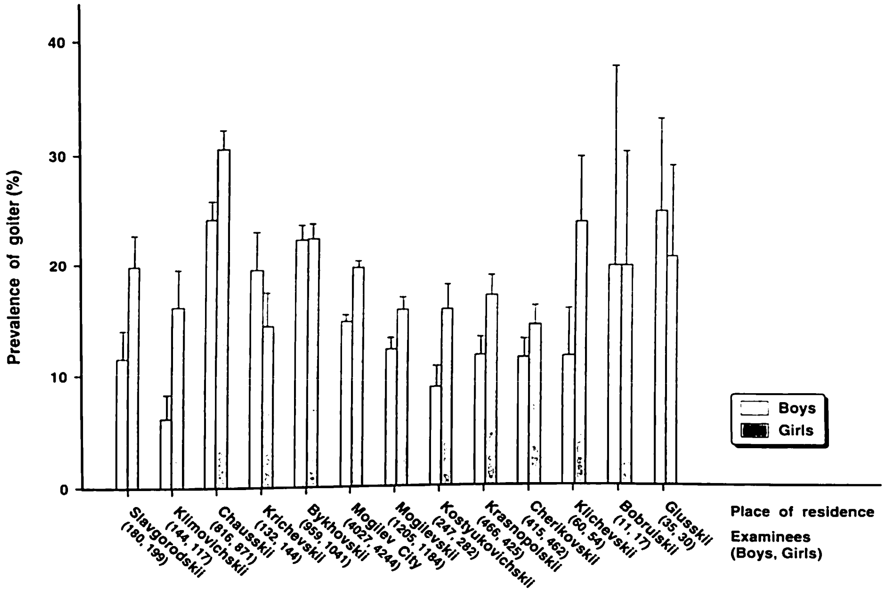

Figure 5. Prevalence of goiter by sex and place of current residence. The whiskers denote the standard errors. See page 2 for the definition of goiter.

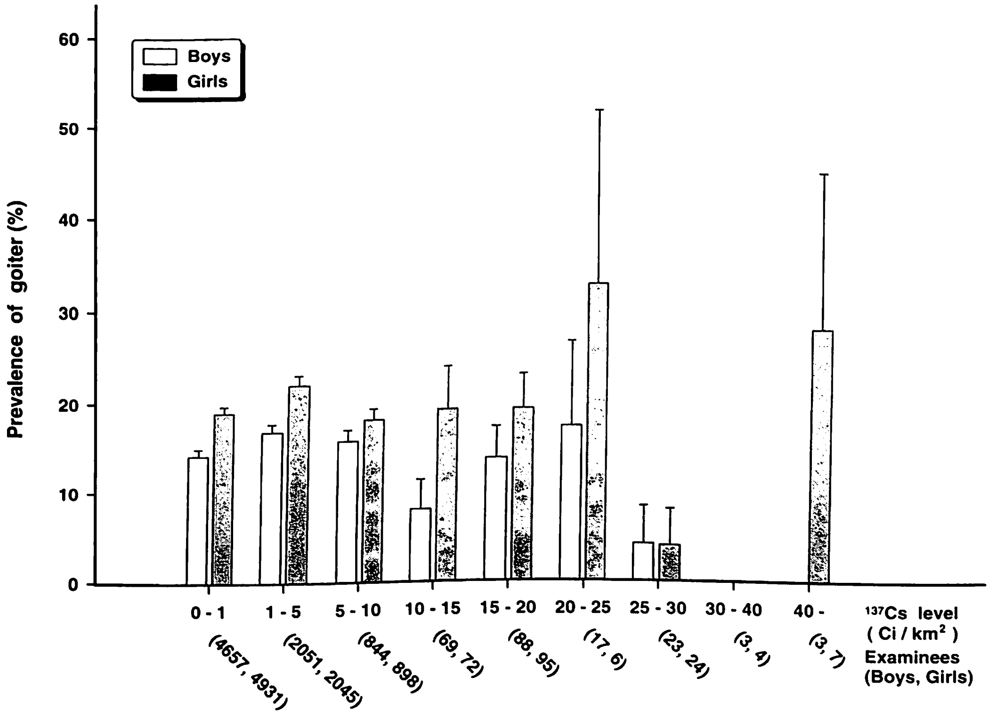

Figure 6. Prevalence of goiter by sex and contamination level (Ci/km^2) in the place of current residence. The whiskers denote the standard errors. See page 2 for the definition of goiter.

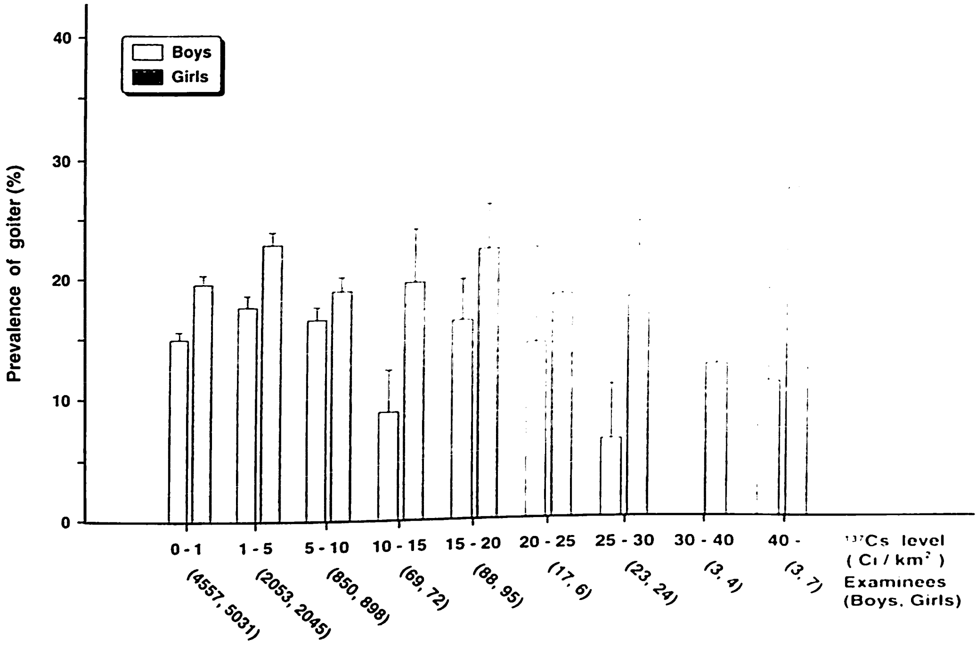

Figure 7. Prevalence of goiter by sex and contamination level (Ci/km^2) in the place of residence at the time of the accident. The whiskers denote the standard errors. See page 2 for the definition of goiter.

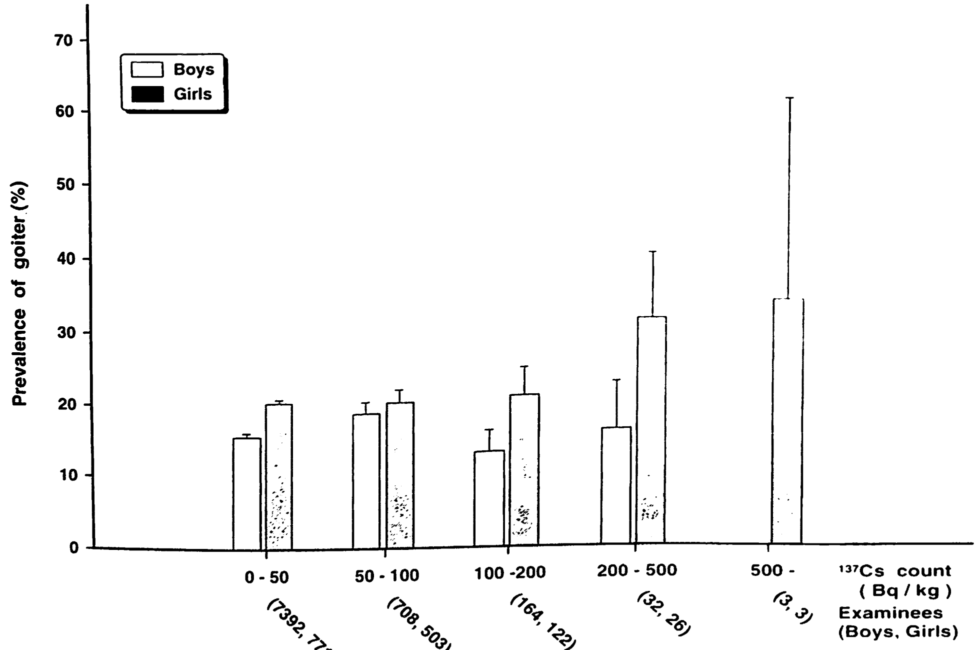

Figure 8. Prevalence of goiter by sex and whole body ^{137}Cs count per kg body weight. The whiskers denote the standard errors. See page 2 for the definition of goiter.

prevalence of goiter and ^{137}Cs specific activity in the body since the number of children with ^{137}Cs specific activity exceeding 200 Bq/kg was very small (Figure 8).

It was not possible to establish any relationship between the prevalence of positive ATG titers and ^{137}Cs specific activity in the body (Figure 9). No relationship was observed between the prevalence of positive AMC titers and ^{137}Cs specific activity in the body (Figure 10). The prevalence of positive titers of ATG and AMC antibodies was higher in girls than in boys. No relationship was observed between the prevalence of positive titers of ATG and AMC antibodies and the soil ^{137}Cs contamination level at the time of the accident or the contamination level in the place of current residence (Figures 11–14).

Table 2 shows the prevalence of thyroid abnormalities by sex and place of residence. Abnormal thyroid echogenity was found in 194 children (147 girls), among whom 103 (79 girls and 24 boys) were registered in 1994. A total of 93 children were found to have abnormal thyroid echogenity with positive ATG and AMC titers in 1994. (By comparison, only 60 children were found to have the same pathology in the period from 1991 to 1993.) Out of the total number of children examined, 21 (7 boys and 14 girls) showed nodules. Two cases of thyroid papillary cancer were found in Belynichskii and Cherikovskii Rayons. Surgery was performed in the Thyroid Oncology Department, Minsk. The diagnosis was confirmed histologically. Cysts were found in 13 girls and 19 boys.

As shown in Table 3, the laboratory findings revealed 75 children with chemical hyperthyroidism (including 50 children from Bykhov City). A total of 43 children were re-examined in a 3-month period (7 subjects refused to be re-examined), but

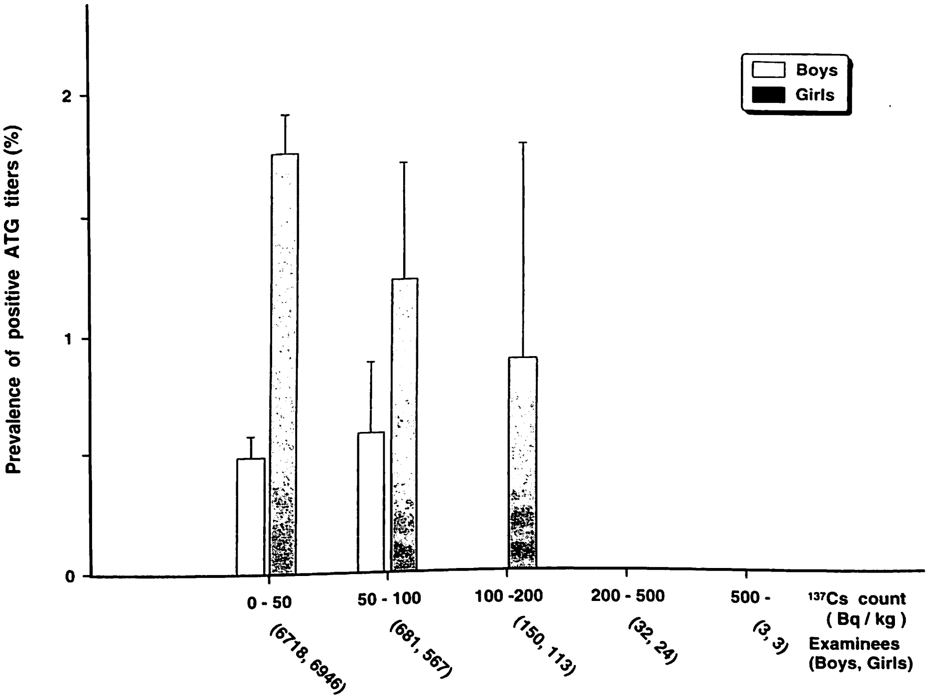

Figure 9. Prevalence of positive ATG titers by sex and whole body ^{137}Cs count per kg body weight. The whiskers denote the standard errors.

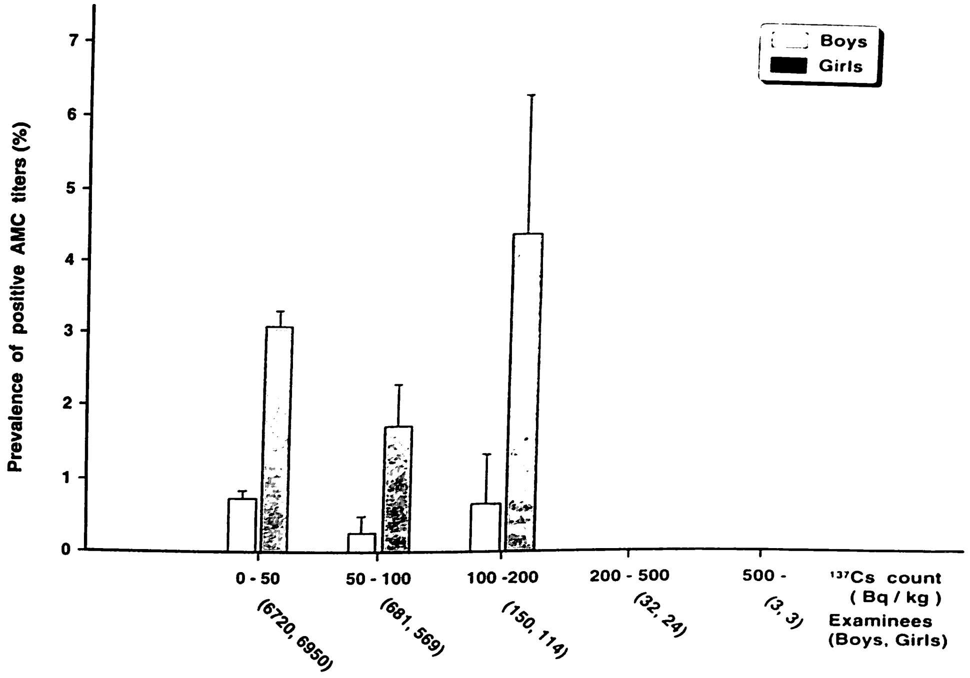

Figure 10. Prevalence of positive AMC titers by sex and whole body ^{137}Cs count per kg body weight. The whiskers denote the standard errors.

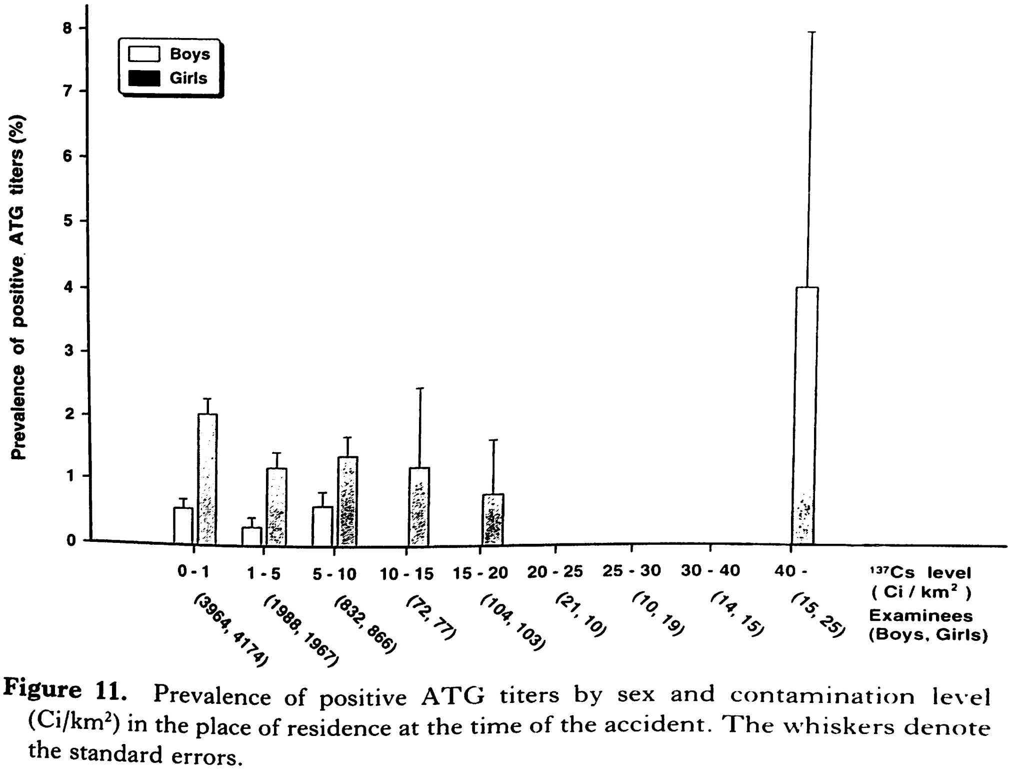

Figure 11. Prevalence of positive ATG titers by sex and contamination level (Ci/km^2) in the place of residence at the time of the accident. The whiskers denote the standard errors.

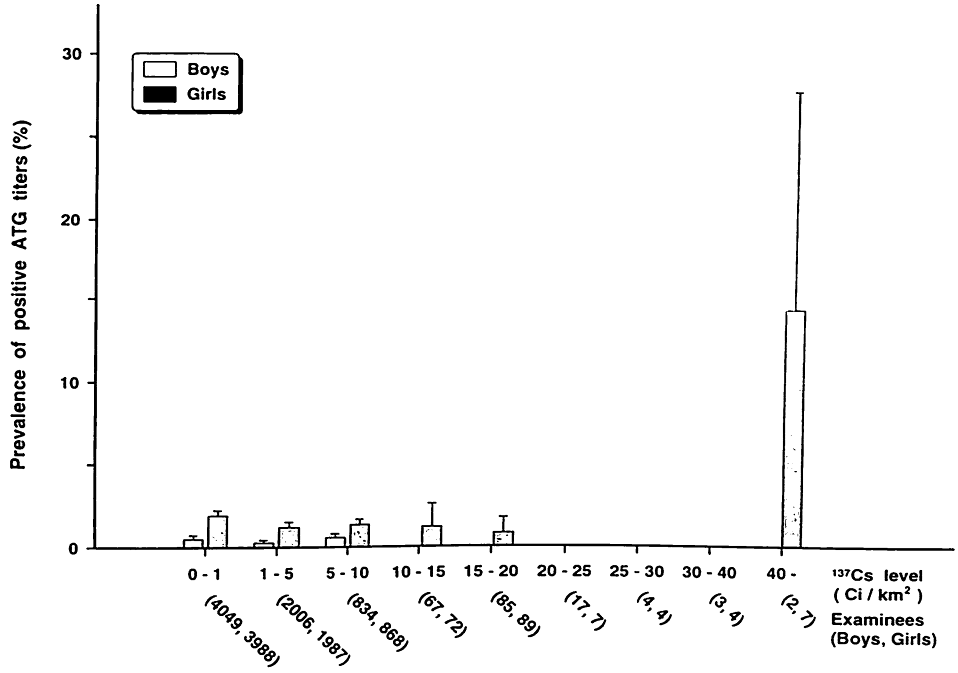

Figure 12. Prevalence of positive ATG titers by sex and contamination level (Ci/km^2) in the place of current residence. The whiskers denote the standard errors.

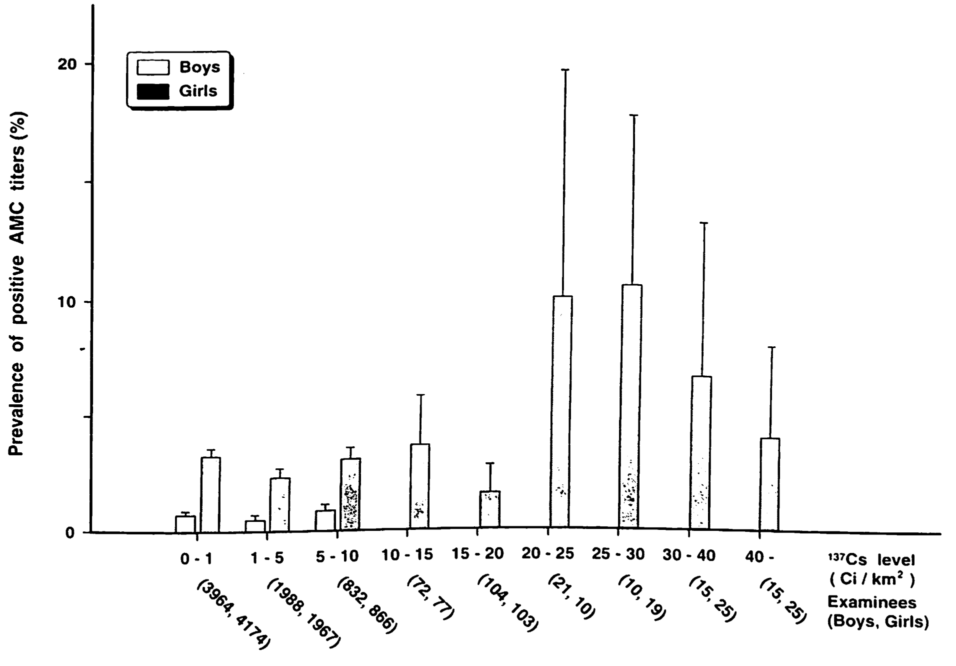

Figure 13. Prevalence of positive AMC titers by sex and contamination level (Ci/km^2) in the place of residence at the time of the accident. The whiskers denote the standard errors.

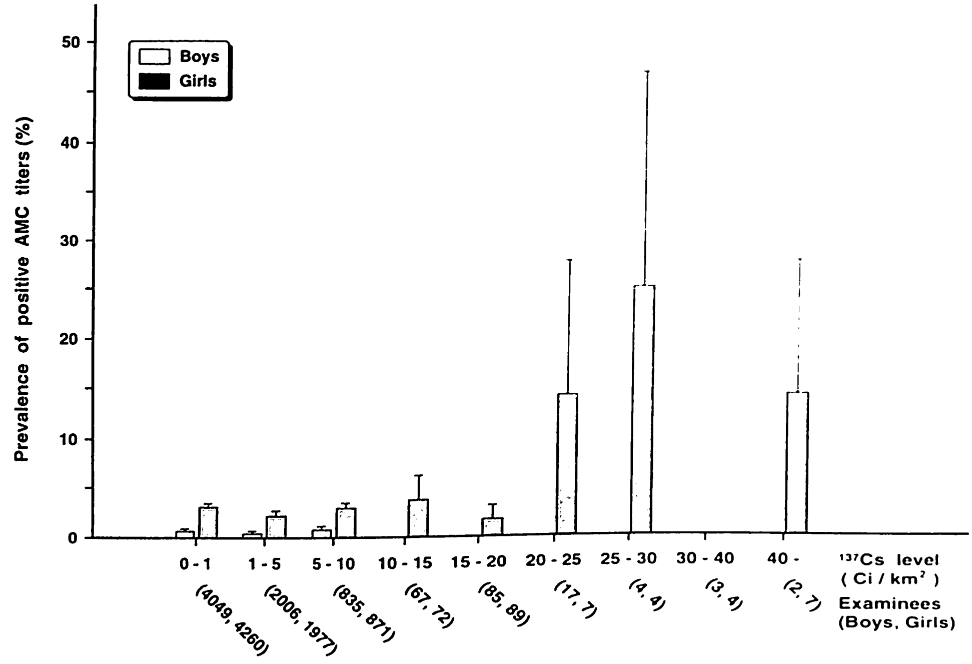

Figure 14. Prevalence of positive AMC titers by sex and contamination level (Ci/km^2) in the place of current residence. The whiskers denote the standard errors.

Table 2. Subjects with thyroid abnormalities by sex and place of residence.

Place of residence	Number of subjects examined		Diagnosis									
			Nodular lesion		Cystic lesion		Abnormal echogenity		Anomaly		Cancer	
	B[a]	G[a]	B	G	B	G	B	G	B	G	B	G
Slavgorodskii	180	199	0	0	0	0	0	5	2	0	0	0
Klimovichskii	144	117	0	0	0	0	2	0	3	2	0	0
Chausskii	816	871	0	1	0	3	8	10	1	2	0	0
Krichevskii	132	144	0	0	0	0	0	0	0	0	0	0
Bykhovskii	959	1041	0	1	0	2	0	6	1	1	0	0
Mogilev City	4028	4245	6	10	12	13	25	92	10	11	0	0
Mogilevskii	1205	1184	1	1	1	1	9	18	0	0	1	0
Kostyukovichskii	247	282	0	0	0	0	0	4	2	1	0	0
Krasnopolskii	467	425	0	0	0	0	0	8	4	3	0	0
Cherikovskii	415	462	0	1	0	0	3	4	1	1	0	1
Klichevskii	60	54	0	0	0	0	0	0	1	0	0	0
Bobruiskii	14	21	0	0	0	0	0	0	0	0	0	0
Glusskii	33	29	0	0	0	0	0	0	0	0	0	0
Total	8700	9075	7	14	13	19	47	147	25	21	1	1

[a] B, boys; G, girls.

Table 3. Number of subjects with hypothyroidism and hyperthyroidism by sex and place of residence.

Place of residence	Number of subjects with measurement			Hypothyroidism[a]			Hyperthyroidism[a]		
	Total	Boys	Girls	Total	Boys	Girls	Total	Boys	Girls
Slavgoroskii	377	180	197	3	1	2	1	0	1
Klimovichskii	249	137	112	0	0	0	0	0	0
Chausskii	1647	802	845	0	0	0	1	1	0
Krichevskii	274	130	144	1	0	1	0	0	0
Bykhovskii	1963	950	1013	0	0	0	50	20	30
Mogikev City	8249	4030	4219	3	1	2	6	4	2
Mogilevskii	2358	1193	1165	3	2	1	15	6	9
Kostyukovichskii	493	231	262	1	1	0	0	0	0
Krasnopolskii	865	453	412	1	0	1	1	0	1
Cherikovskii	848	409	439	0	0	0	0	0	0
Klichevskii	111	60	51	0	0	0	0	0	0
Bobruiskii	25	10	15	0	0	0	0	0	0
Glusskii	57	31	26	0	0	0	0	0	0
Total	17 516	8616	8900	12	5	7	74	31	43

[a] Diagnosed when free $T_4 < 10.0$ pmol/L and TSH > 2.90 μIU/mL.

[b] Diagnosed when free $T_4 > 25.0$ pmol/L and TSH < 0.24 μIU/mL.

since the hormonal status was normal, no definite diagnosis has been established as yet.

A positive ATG antibody titers was observed in 180 children including 141 girls and a positive AMC titer was found in 306 children including 249 girls. A positive titer of both ATG and AMC antibodies was found more frequently in girls than in boys (Table 4).

Urinary iodine and creatinine content was measured in 4 rayons and in Mogilev City. The results are shown in Table 5. The highest percentage of low urinary iodine content was registered in children from Krasnopolskii (36%) and Cherikovskii (31.8%) Rayons.

The relationship between urinary iodine content and serum FT_4 and TSH levels and the residual of thyroid volume after adjustment for age, height and weight was studied. A statistically significant correlation was observed between the urinary iodine content and serum FT_4 and TSH levels but the respective correlation coefficients were small (Figures 15 and 16): the 95% confidence interval of the correlation coefficient was $-0.09 < \rho < -0.02$ for urinary iodine and FT_4 level and $0.05 < \rho < 0.14$ for urinary iodine and TSH levels. No significant correlation was observed between urinary iodine content and residual thyroid volume (Figure 17): the 95% confidence interval of the correlation coefficient was $-0.02 < \rho < 0.06$.

At the present time, special attention is being paid to re-investigations into urinary iodine content in children with thyroid abnormalities. These investigations should be continued.

Table 4. Prevalence of positive ATG (anti-thyroglobulin antibody) and AMC (anti-microsome antibody) titers by sex and place of residence.[a]

Place of residence	Number of subjects measured			Antibody					
				Anti-thyroglobulin			Anti-microsome		
	Total	Boys	Girls	Total	Boys	Girls	Total	Boys	Girls
Slavgorodskii	377	180	197	3 (0.8)	0	3 (1.5)	10 (2 7)	1 (0.6)	9 (4.6)
Klimovichskii	171	97	74	1 (0.6)	1 (1.0)	0	3 (1.8)	3 (3.1)	0
Chausskii	1674	802	845	12 (0.7)	3 (0.4)	9 (1.1)	22 (1.3)	4 (0.5)	18 (2.1)
Krichevskii	274	130	144	2 (0.7)	0	2 (1.4)	1 (0.4)	0	1 (0.7)
Bykhovskii	1967	950	1017	22 (1.1)	7 (0.7)	15 (1.5)	42 (2.1)	9 (0.9)	33 (3.2)
Mogilev City	7051	3447	3604	98 (1.4)	21 (0.6)	77 (2.1)	150 (2.1)	26 (0.8)	124 (3.4)
Mogilevskii	2353	1189	1164	18 (0.8)	4 (0.3)	14 (1.2)	38 (1.6)	8 (0.7)	30 (2.6)
Kostyukovichskii	493	231	262	3 (0.6)	0	3 (1.1)	8 (1.6)	1 (0.4)	7 (2.8)
Krasnopolskii	865	453	412	12 (1.4)	1 (0.2)	11 (2.7)	16 (1.8)	2 (0.4)	14 (3.4)
Cherikovskii	846	408	438	7 (0.8)	2 (0.5)	5 (1.1)	13 (1.5)	3 (0.7)	10 (2.3)
Klichevskii	111	60	51	1 (0.9)	0	1 (2.0)	1 (0.9)	0	1 (2.0)
Bobruiskii	25	10	15	0	0	0	1 (4.0)	0	1 (6.7)
Glusskii	56	31	25	1 (1.8)	0	1 (4.1)	1 (1.8)	0	1 (4.1)
Total	16 236	7988	8248	180 (1.1)	39 (0.5)	141 (1.7)	306 (1.9)	57 (0.7)	249 (3.0)

[a] Number of subjects with percentages in parentheses.

Table 5. Number of subjects with low urinary iodine excretion by place of residence.

Place of residence	Number of subjects examined	Number of subjects with low urinary iodine excretion (< 10 μg/dL)
Mogilev City	1290	329 (27.0%)
Chausskii	170	37 (21.8%)
Cherikovskii	855	27 (31.8%)
Bykhovskii	80	7 (8.7%)
Krasnopolskii	25	9 (36.0%)
Total	2420	409 (16.9%)

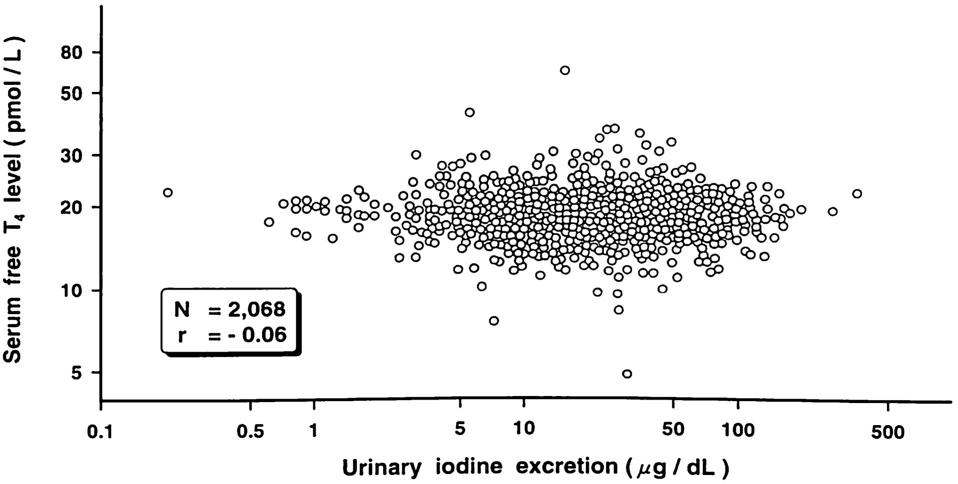

Figure 15. Scatter plots of urinary iodine excretion and serum free T_4 level.

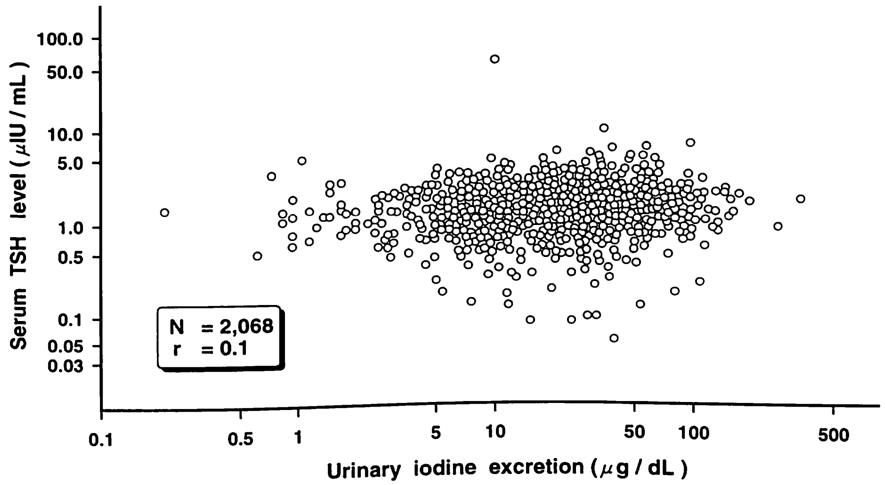

Figure 16. Scatter plots of urinary iodine excretion and serum TSH level.

3.4 Hematological studies

Tables and figures below show the results of the examinations based on hematological parameters relative to age, sex, place of residence, ^{137}Cs contamination level of the territory and specific activity. The medians of the hematological parameters of the hemogram were mainly within the limits of the expected age range.

The relationship between hemoglobin level and age and sex is shown in Figure 18. A trend towards an increase in hemoglobin level with age was noted. The median of hemoglobin level was higher in boys than in girls and the difference was more pronounced from 12 years of age. The median of Hb level increased with age in boys but leveled off in girls from 12 to 13 and then decreased slightly at the age of 15 to 17. We consider these changes to be associated with hormonal changes and a decrease in endogenic iron content during puberty. Of the 21 girls found to have anemia, 14

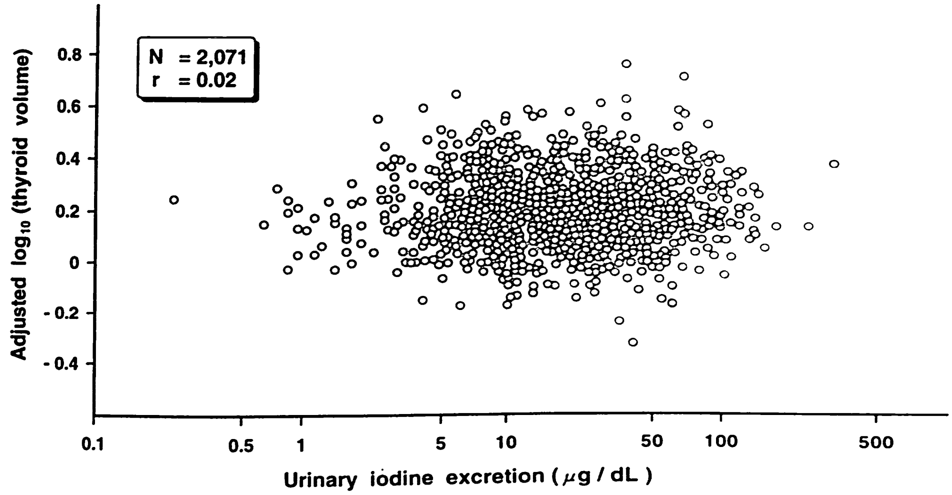

Figure 17. Scatter plots of urinary iodine excretion and the residual of the logarithm of thyroid volume after adjustment for age, height and weight.

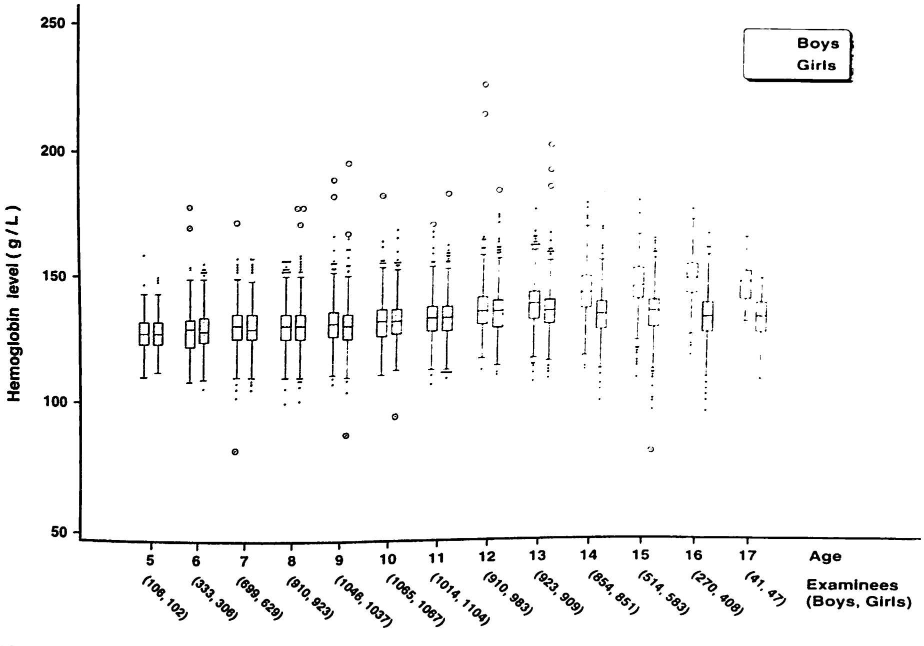

Figure 18. The box-and-whisker plots of hemoglobin level by sex and age. See Figure 2 for details.

(66.7%) were older than 10 years of age.

The relationship between MCV and age and sex is shown in Figure 19. The median of MCV was within normal range in all age and sex groups. The trend was towards an increase in MCV with age. MCV was higher in girls than in boys at all ages. A decrease in MCV level (< 80 fl) was registered in 980 children, while anemia was found in 13 children. A total of 31 children were found to have anemia, and 41.9% of anemia cases had a reduced MCV value.

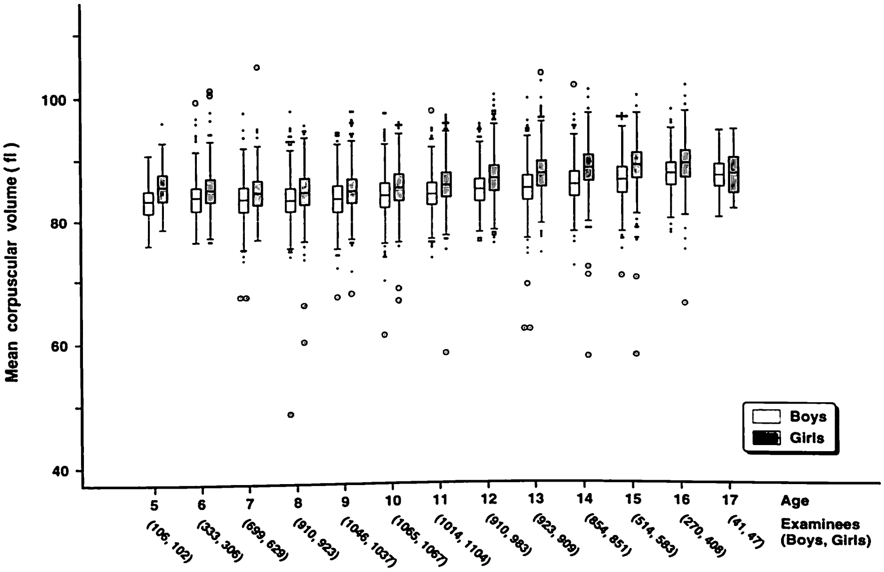

Figure 19. The box-and-whisker plots of mean corpuscular volume by sex and age. See Figure 2 for details.

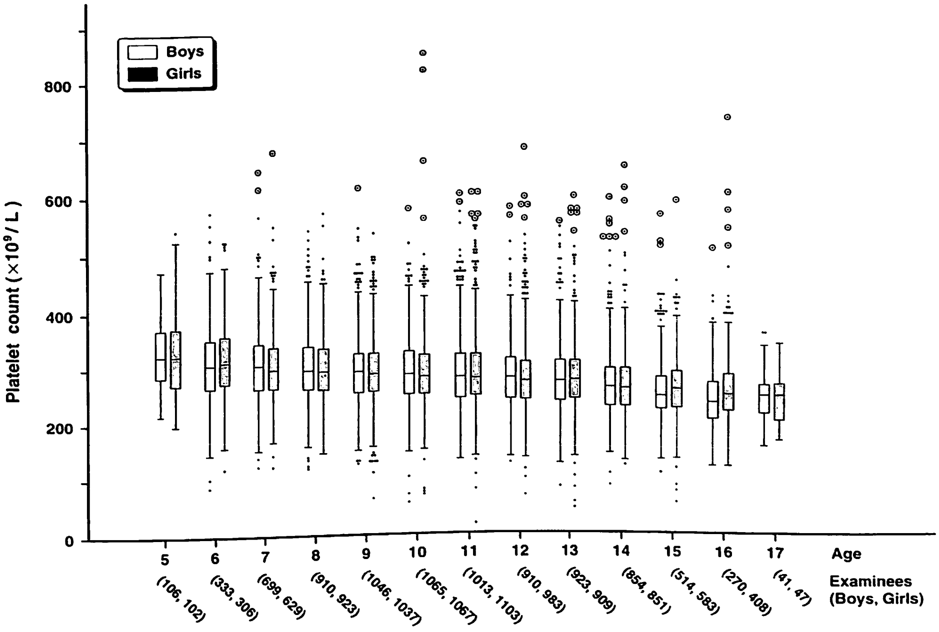

Figure 20. The box-and-whisker plots of platelet count by sex and age. See Figure 2 for details.

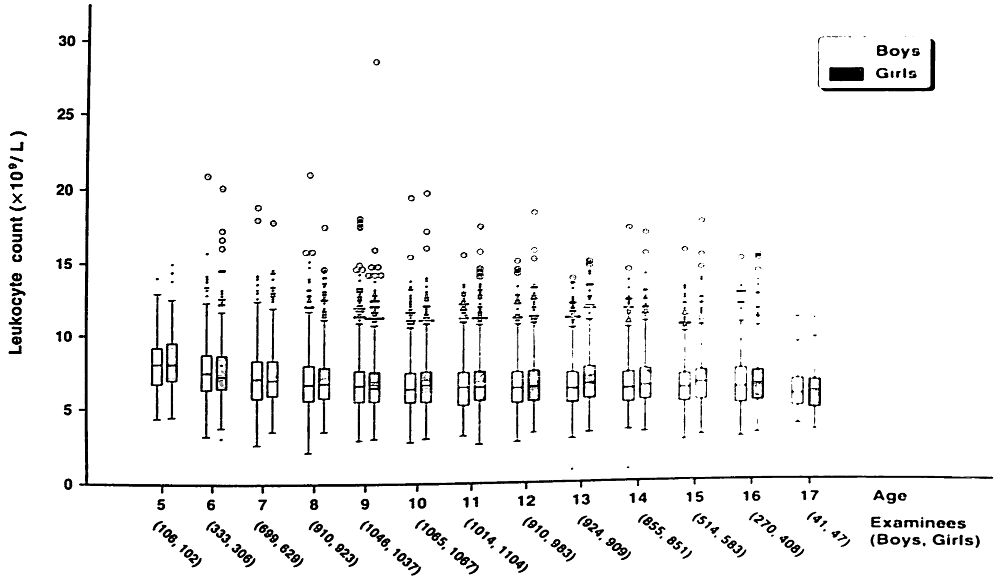

Figure 21. The box-and-whisker plots of leukocyte count by sex and age. See Figure 2 for details.

Figure 20 shows the relationship between platelet count and age and sex. The median of PLT was within normal range in both boys and girls.

Figure 21 shows the relationship between WBC and age and sex. The median of WBC was within normal limits irrespective of sex and age.

The median of neutrophil count remained relatively stable up to 11 years of age but increased thereafter and was more pronounced in girls.

A rather high level of lymphocytes was noted in the group of children aged 5 to 6 years. The lymphocyte count leveled off in children aged 8 to 13 years. A decrease in the median of lymphocytes was noted in children aged 14 to 17 years.

Tables 6A and 6B show the frequency of deviations from normal limits in the hemograms of boys and girls in relation to the place of residence, respectively.

The results of the general blood count in 8,629 boys show the following hematological abnormalities: anemia in 10 boys (0.1%) living mainly in Mogilev City and Mogilevskii Rayon; leukopenia in 58 boys (0.7%), 44 of whom live in Mogilev City; thrombocytopenia in 5 boys (0.1%); lymphopenia in 944 boys (10.9%), neutropenia in 21 boys (0.2%); eosinophilia in 1,274 boys (14.8%); and leukocytosis in 309 boys (3.6%). The highest and lowest frequency of leukocytosis in boys was registered in Krichevskii Rayon (14.3%) and Mogilev City (1.5%), respectively. The most remarkable deviations from the normal range were noted in eosinophil count. The highest frequency of eosinophilia was found in the following rayons: Krichevskii – 39.8%, Belynichskii – 33.3%, Klimovichskii – 30.8%, Slavgorodskii – 29.7% and Cherikovskii – 20.8%. The Pelger anomaly of neutrophils was found in 4 boys. Two boys were found to have gastrointestinal ailments (gastroduodenitis and dyskinesia of the biliary tract).

Out of 8,921 girls undergoing examinations by general blood count, 21 (0.2%) or

Table 6A. Frequency of boys with hematological abnormalities by place of residence.[a]

Blood analysis		Place of residence[b]																Total
Item (unit)[c]	Abnormality criteria	SLA	KLI	CHA	KRI	BYK	MGC	MGR	KOS	KRA	CHR	KLC	BEL	BBR	BBC	GLU	GOR	
Hb (g/L)	< 110						5 (0.1)	3 (0.3)		1 (0.2)	1 (0.2)							10 (0.1)
	> 180					2 (0.2)	1 (0.0)		1 (0.4)		1 (0.2)							5 (0.1)
WBC (×10⁹/L)	< 3.8			2 (0.3)		5 (0.5)	44 (1.1)	3 (0.3)	3 (1.3)		1 (0.2)							58 (0.7)
	> 10.6	11 (6.0)	6 (4.2)	38 (4.8)	19 (14.3)	47 (4.9)	62 (1.5)	54 (4.5)	7 (3.0)	37 (8.0)	24 (5.9)	3 (5.0)				1 (3.4)		309 (3.6)
PLT (×10⁹/L)	< 100						4 (0.1)			1 (0.2)								5 (0.1)
	> 440	5 (2.7)		16 (2.0)	6 (4.5)	15 (1.6)	32 (0.8)	17 (1.4)	32 (13.9)	6 (1.3)	6 (1.5)				1 (16.7)			136 (1.6)
MCV (fl)	< 80	9 (4.9)	13 (9.1)	81 (10.2)	7 (5.3)	64 (6.7)	367 (9.1)	53 (4.5)	11 (4.8)	46 (10.0)	26 (6.4)	1 (1.7)		1 (20.0)	1 (16.7)	3 (10.3)		683 (7.9)
	> 100			1 (0.1)					1 (0.4)	1 (0.2)								3 (0.0)
Ly (×10⁹/L)	< 1.2		2 (1.4)	103 (13.0)	1 (0.8)	89 (9.4)	494 (12.3)	105 (8.8)	37 (16.1)	49 (10.6)	58 (14.2)	1 (1.7)			2 (33.3)	2 (6.9)	1 (20.0)	944 (10.9)
	> 3.5	21 (11.5)	11 (7.7)	70 (8.8)	45 (33.8)	104 (10.9)	202 (5.0)	107 (9.0)	22 (9.6)	19 (4.1)	11 (2.7)	6 (10.0)		1 (20.0)	1 (16.7)	7 (24.1)		627 (7.3)
Ne (×10⁹/L)	< 1.4			4 (0.5)	1 (0.8)		12 (0.3)	2 (0.2)		1 (0.2)	1 (0.2)							21 (0.2)
	> 6.6	8 (4.4)	7 (4.9)	57 (7.2)	13 (9.8)	57 (6.0)	87 (2.2)	59 (5.0)	10 (4.3)	52 (11.3)	29 (7.1)	4 (6.7)				1 (3.4)		384 (4.5)
Eo (×10⁹/L)	> 0.5	54 (29.7)	44 (30.8)	168 (21.2)	53 (39.8)	90 (9.5)	417 (10.3)	205 (17.3)	45 (19.6)	95 (20.6)	85 (20.8)	14 (23.3)	1 (33.3)			3 (10.3)		1274 (14.8)
Mo (×10⁹/L)	< 0.12	77 (42.3)	20 (14.0)	58 (7.3)	52 (39.1)	107 (11.3)	328 (8.1)	101 (8.5)	26 (11.3)	19 (4.1)	9 (2.2)	2 (3.3)		2 (40.0)	1 (16.7)	5 (17.2)		807 (9.4)
	> 1.00		6 (4.2)	45 (5.7)		101 (10.6)	182 (4.5)	62 (5.2)	15 (6.2)	54 (11.7)	40 (9.8)	3 (5.0)						508 (5.9)
Number of children measured		182	143	793	133	951	4031	1188	230	461	409	60	3	5	6	29	5	8629

[a] Parenthetic entries refer to the percentage of the subjects while empty spaces denote the absence of subjects with abnormalities.

[b] SLA, Slavgorodskii; KLI, Klimovichskii; CHA, Chausskii; KRI, Krichevskii, BYK, Bykhovskii; MGC, Mogilev City; MGR, Mogilevskii; KOS, Kostyukovichskii; KRA, Krasnopolskii; CHR, Cherikovskii; KLC, Klichevskii; BEL, Belynichskii; BBR, Bobruiskii; BBC, Bobruisk City; GLU, Glusskii. GOR, Goretskii.

[c] Hb, hemoglobin; WBC, white blood cell (leukocyte); PLT, platelet; MCV, mean corpuscular volume; Ly, lymphocyte; Ne, neutrophil; Eo, eosinophil; Mo, monocyte.

Table 6B. Frequency of girls with hematological abnormalities by place of residence.[a]

Blood analysis		Place of residence[b]															Total
Item (unit)[c]	Abnormality criteria	SLA	KLI	CHA	KRI	BYK	MGC	MGR	KOS	KRA	CHR	KLC	BBR	BBC	GLU	GOR	
Hb (g/L)	< 110			1			12	4		3	1						21
				(0.1)			(0.3)	(0.3)		(0.7)	(0.2)						(0.2)
	> 160			3		4	11	5	1	4	2						30
				(0.4)		(0.4)	(0.3)	(0.4)	(0.4)	(1.0)	(0.4)						(0.3)
WBC (×10^9/L)	< 3.6			3		2	26	2									33
				(0.4)		(0.2)	(0.6)	(0.2)									(0.4)
	> 11.0	5	1	36	16	40	45	35	4	20	20	1					223
		(2.5)	(0.9)	(4.3)	(11.0)	(3.9)	(1.1)	(3.0)	(1.5)	(4.8)	(4.5)	(2.0)					(2.5)
PLT (×10^9/L)	< 100			3		1	5	1	2	1	1						14
				(0.4)		(0.1)	(0.1)	(0.1)	(0.8)	(0.2)	(0.2)						(0.2)
	> 440	4	1	13	3	22	32	6	53	5	7						146
		(2.0)	(0.9)	(1.6)	(2.1)	(2.2)	(0.8)	(0.5)	(20.1)	(1.2)	(1.6)						(1.6)
MCV (fl)	< 80	3	1	29	7	34	155	26	4	13	19		1				292
		(1.5)	(0.9)	(3.5)	(4.8)	(3.3)	(3.7)	(2.2)	(1.5)	(3.1)	(4.3)		(5.3)				(3.3)
	> 100			3			2	1									6
				(0.4)			(0.0)	(0.1)									(0.1)
Ly (×10^9/L)	< 1.2	3	5	119	1	84	485	85	32	35	56	1		1		1	908
		(1.5)	(4.4)	(14.2)	(0.7)	(8.3)	(11.5)	(7.3)	(12.1)	(8.3)	(12.5)	(2.0)		(50.0)		(16.7)	(10.2)
	> 3.5	35	7	84	50	120	203	95	21	35	21	6	6		3		686
		(17.6)	(6.2)	(10.0)	(34.5)	(11.8)	(4.8)	(8.2)	(8.0)	(8.3)	(4.7)	(12.0)	(31.6)		(13.0)		(7.7)
Ne (×10^9/L)	< 1.4			1			14	2	1								18
				(0.1)			(0.3)	(0.2)	(0.4)								(0.2)
	> 6.6	10	3	72	10	65	111	67	13	33	24	4	1				413
		(5.0)	(2.7)	(8.6)	(6.9)	(6.4)	(2.6)	(5.8)	(4.9)	(7.8)	(5.4)	(8.0)	(5.3)				(4.6)
Eo (×10^9/L)	> 0.5	38	24	173	45	109	374	174	42	74	86	12	3		1	1	1156
		(19.1)	(21.1)	(20.6)	(31.0)	(10.7)	(8.9)	(15.0)	(15.9)	(17.6)	(19.2)	(24.0)	(15.8)		(4.3)	(16.7)	(13.0)
Mo (×10^9/L)	< 0.12	80	20	72	53	99	350	112	26	31	7	1	5		4	1	861
		(40.2)	(17.7)	(8.6)	(36.6)	(9.7)	(8.3)	(9.6)	(9.8)	(7.4)	(1.6)	(2.0)	(26.3)		(17.4)	(16.7)	(9.7)
	> 1.00		1	54	3	90	175	65	9	31	52	4		1		1	486
			(0.9)	(6.4)	(2.1)	(8.8)	(4.2)	(5.6)	(3.4)	(7.4)	(11.6)	(8.0)		(50.0)		(16.7)	(5.4)
Number of children measured		199	113	838	145	1018	4215	1161	264	421	447	50	19	2	23	6	8921

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[a] Parenthetic entries refer to the percentage of the subjects while empty spaces denote the absence of subjects with abnormalities.

[b] SLA, Slavgorodskii; KLI, Klimovichskii; CHA, Chausskii; KRI, Krichevskii, BYK, Bykhovskii; MGC, Mogilev City; MGR, Mogilevskii; KOS, Kostyukovichskii; KRA, Krasnopolskii; CHR, Cherikovskii; KLC, Klichevskii; BBR, Bobruiskii; BBC, Bobruisk City; GLU, Glusskii. GOR, Goretskii.

[c] Hb, hemoglobin; WBC, white blood cell (leukocyte); PLT, platelet; MCV, mean corpuscular volume; Ly, lymphocyte; Ne, neutrophil; Eo, eosinophil; Mo, monocyte.

2.1 times as many cases as in boys were shown to have anemia. Twelve of these girls live in Mogilev City. Moreover, 33 girls (0.4%) had leukopenia, 26 of whom live in Mogilev City; 18 (0.2%) had neutropenia; 908 (10.2%) had lymphopenia and 223 (2.5%) had leukocytosis. Two girls showed thrombocytopenic purpura (1 girl each from Mogilev City and Mogilevskii Rayon). One girl aged 9 (Krichevskii Rayon) showed a leukemoid reaction of the lymphocytic type.

A high frequency of leukocytosis (11%) was registered in children from Krichevskii Rayon. Most of the children with a high WBC in their hemograms showed clinical symptoms such as acute respiratory disease or acute attacks of chronic inflammatory disease.

Tables 7A and 7B show the frequency of deviations from the normal range in the hemogram for boys and girls in relation to the ^{137}Cs activity value (Bq/kg), respectively.

The group of children in which the ^{137}Cs specific activity ranged from 0 to 50 Bq/kg was the largest, and most of the deviations were registered in this group. Because of the small size of the other groups, it was difficult to conduct a comparative analysis. A higher frequency of eosinophilia, neutrophilia and lymphopenia was noted with an increase in ^{137}Cs specific activity in both boys and girls. In 32 boys whose level of ^{137}Cs specific activity was 200 Bq/kg or higher, the following deviations from the normal limits were found: leukocytosis in 4, lymphopenia in 1, thrombocytosis in 1, neutrophilia in 4 and eosinophilia in 3 boys. A group of 29 girls whose level of ^{137}Cs specific activity was 200 Bq/kg and higher, showed the following: thrombocytosis in 1, lymphopenia in 3 and eosinophilia in 7 girls.

We are now focusing attention on a more comprehensive re-examination of children with deviations from the normal limits starting from 15 May 1991. The results of the re-examinations are shown in Table 8.

The Hb level returned to normal range in the re-examined children with a low Hb level (16 cases) without any course of medical treatment. Iron deficiency anemia was confirmed in 6 children who later underwent a course of aetiopathogenic treatment. Out of 4 children with leukopenia, 1 showed gastroduodenitis with concomitant intestinal lambliasis and 3 showed leukopenia with no clinical signs. A thorough re-examination revealed 550 children with eosinophilia: 91 (16.5%) with allergic abnormality in the form of rhinosinusopathy, obstructive bronchitis, bronchial asthma, atopic dermatitis and food allergy; 51 (9.3%) with gastrointestinal tract disorders; and 5 (0.9%) with rhinopharyngeal abnormality. An attempt to study seasonal difference in the prevalence of eosinophilia was made but it is difficult to draw a conclusion on the difference because the number of children examined in both of spring and autumn was small.

We studied the relationship between ferritin level and age and sex in children with normal MCV and Hb values (Figure 22). We also studied ferritin content in relation to Hb level (Figure 23). Out of 27 children with $Hb < 110$ g/L, 13 (48.2%) revealed a decrease in ferritin level. Similarly, a total of 773 assays of ferritin content were conducted in children with $MCV < 80$ fl (Figure 24).

Table 7A. Frequency of boys with hematological abnormalities by ^{137}Cs level.[a]

Blood analysis		Whole body ^{137}Cs count per body weight (Bq/kg)					Total
Item (unit)[b]	Abnormality criteria	0–50	50–100	100–200	200–500	500–	
Hb (g/L)	< 110	9 (0.1)	1 (0.1)				10 (0.1)
	> 180	4 (0.1)	1 (0.1)				5 (0.1)
WBC ($\times10^9$/L)	< 3.8	55 (0.7)	4 (0.6)				59 (0.7)
	> 10.6	249 (3.2)	46 (6.5)	12 (7.6)	4 (12.5)		311 (3.6)
PLT ($\times10^9$/L)	< 100	5 (0.1)					5 (0.1)
	> 440	116 (1.5)	17 (2.4)	3 (1.9)	1 (3.1)		137 (1.6)
MCV (fl)	< 80	638 (8.2)	46 (6.5)	7 (4.5)	1 (3.1)		692 (8.0)
	> 100	1 (0.0)	1 (0.1)				2 (0.0)
Ly ($\times10^9$/L)	< 1.2	856 (11.0)	80 (11.3)	13 (8.3)	1 (3.1)		950 (10.9)
	> 3.5	541 (6.9)	73 (10.3)	12 (7.6)	2 (6.3)		628 (7.2)
Ne ($\times10^9$/L)	< 1.4	20 (0.3)		1 (0.6)			21 (0.2)
	> 6.6	318 (4.1)	54 (7.6)	12 (7.6)	4 (12.5)	1 (33.3)	389 (4.5)
Eo ($\times10^9$/L)	> 0.5	1105 (14.2)	148 (20.9)	28 (17.8)	3 (9.4)		1284 (14.8)
Mo ($\times10^9$/L)	< 0.12	704 (9.0)	82 (11.6)	18 (11.5)	3 (9.4)		807 (9.3)
	> 1.00	452 (5.8)	51 (7.2)	11 (7.0)			514 (5.9)
Number of children measured		7785	707	157	32	3	8684

[a] Parenthetic entries refer to the percentage of the subjects while empty spaces denote the absence of subjects with abnormalities.

[b] Hb, hemoglobin; WBC, white blood cell (leukocyte); PLT, platelet; MCV, mean corpuscular volume; Ly, lymphocyte; Ne, neutrophil; Eo, eosinophil; Mo, monocyte.

Table 7B. Frequency of girls with hematological abnormalities by ^{137}Cs level.[a]

Blood analysis		Whole body ^{137}Cs count per body weight (Bq/kg)					Total
Item (unit)[b]	Abnormality criteria	0–50	50–100	100–200	200–500	500–	
Hb (g/L)	< 110	18 (0.2)	2 (0.3)	1 (0.9)			21 (0.2)
	> 160	27 (0.3)	3 (0.5)				30 (0.3)
WBC ($\times10^9$/L)	< 3.6	32 (0.4)	1 (0.2)				33 (0.4)
	> 11.0	198 (2.4)	21 (3.5)	4 (3.5)			223 (2.5)
PLT ($\times10^9$/L)	< 100	14 (0.2)					14 (0.2)
	> 440	130 (1.6)	13 (2.2)	3 (2.7)	1 (3.8)		147 (1.6)
MCV (fl)	< 80	272 (3.3)	18 (3.0)	2 (1.8)	1 (3.8)		293 (3.3)
	> 100	6 (0.1)					6 (0.1)
Ly ($\times10^9$/L)	< 1.2	853 (10.4)	44 (7.4)	11 (9.7)	3 (11.5)		911 (10.2)
	> 3.5	612 (7.5)	65 (10.9)	9 (8.0)	1 (3.8)		687 (7.7)
Ne ($\times10^9$/L)	< 1.4	16 (0.2)	1 (0.2)		1 (3.8)		18 (0.2)
	> 6.6	373 (4.5)	35 (5.9)	9 (8.0)	1 (3.8)		418 (4.7)
Eo ($\times10^9$/L)	> 0.5	1002 (12.2)	121 (20.3)	29 (25.7)	7 (26.9)		1159 (13.0)
Mo ($\times10^9$/L)	< 0.12	786 (9.6)	58 (9.7)	14 (12.4)	3 (11.5)		861 (9.6)
	> 1.00	446 (5.4)	34 (5.7)	7 (6.2)	1 (3.8)		488 (5.5)
Number of children measured		8210	597	113	26	3	8949

[a] Parenthetic entries refer to the percentage of the subjects while empty spaces denote the absence of subjects with abnormalities.

[b] Hb, hemoglobin; WBC, white blood cell (leukocyte); PLT, platelet; MCV, mean corpuscular volume; Ly, lymphocyte; Ne, neutrophil; Eo, eosinophil; Mo, monocyte.

Table 8. Results of re-examination of children found to have hematological abnormalities at the screening.

Blood analysis		Number of children with abnormalities at screening	Number of children undergoing re-examination	Results of re-examination
Item (unit)[a]	Abnormality criteria			
Hb (g/L)	< 110	31	22	16 - normal 6 - iron deficiency anemia
WBC (×10⁹/L)	< 3.8 for boys < 3.6 for girls	91	50	46 - normal 4 - leukopenia
PLT (×10⁹/L)	< 100	19	16	13 - normal 1 - thrombocytopenia 2 - thrombocytopenic purpura
Eo (×10⁹/L)	> 0.5	2443	550	491 - normal 59 - eosinophilia

[a] Hb, hemoglobin; WBC, white blood cell (leukocyte); PLT, platelet; Eo, eosinophil.

Eleven (35.5%) children (8 girls and 3 boys) revealed anemia with a simultaneous decrease in MCV and ferritin levels.

The following children with an established hematological diagnosis are under the observation of a hematologist: 4 boys with Pelger neutrophil anomaly, 2 girls with thrombocytopenic purpura, and 1 girl with Hodgkin's disease, stage II (born in 1982 and living in Mogilev City; ^{137}Cs specific activity is 552 Bq/kg). The diagnosis of Hodgkin's disease was confirmed with the help of biopsy investigations and CT, and the girl underwent a course of chemotherapy and irradiation treatment in accordance with the German Program of Childhood Oncology Society.

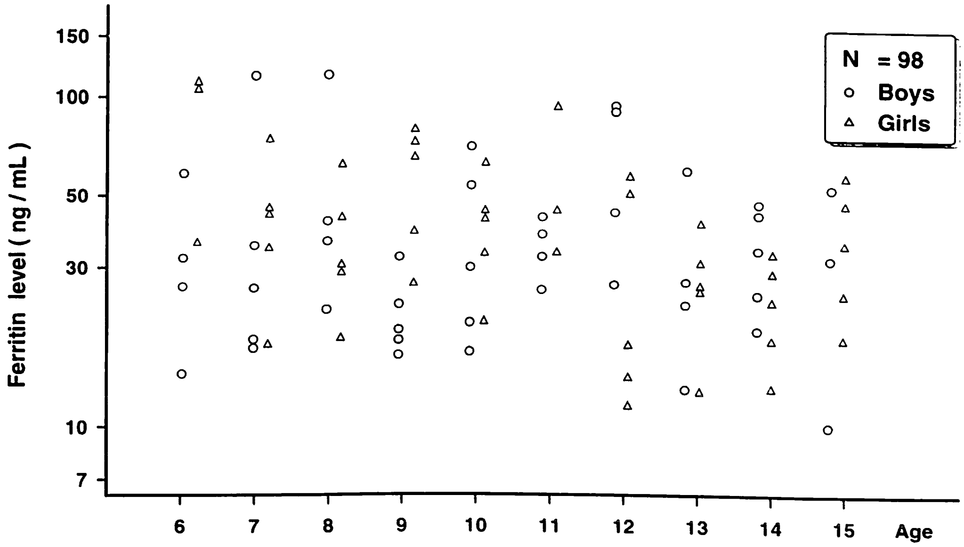

Figure 22. Distribution of ferritin level by age and sex in hematologically normal children.

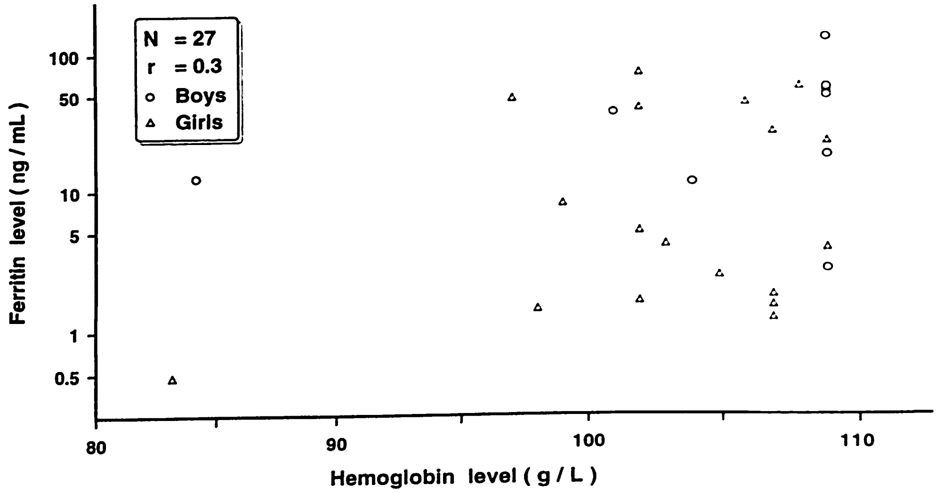

Figure 23. Scatter plots of hemoglobin (Hb) and ferritin levels in children with Hb less than 110 g/L.

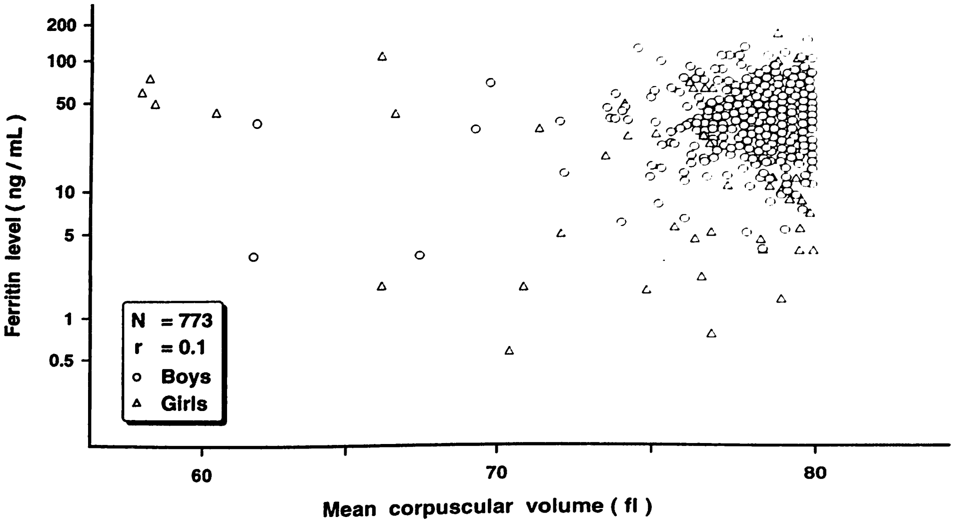

Figure 24. Scatter plots of mean corpuscular volume (MCV) and ferritin levels in children with MCV less than 80 fl.

4. Summary and Conclusions

Whole body ^{137}Cs concentration

On the basis of the analysis of data on ^{137}Cs content in the body of the examined children (both boys and girls) residing in Mogilev Oblast, it should be noted that no significant differences were observed in the ^{137}Cs content levels measured in the period from 1991 to 1994. Most of the ^{137}Cs specific activity values ranged from 10 to 80 Bq/kg.

Thyroid examinations

An increase in autoimmune thyroiditis was noted in 1994, 91% of the total number of thyroiditis cases being children aged 12 to 16 years.

It is difficult to establish the relationship between the prevalence of goiter in children and the ^{137}Cs specific activity in the body because the group of children with ^{137}Cs specific activity higher than 200 Bq/kg was very small.

No relationship was observed between the prevalence of positive titers of ATG or AMC antibodies and the ^{137}Cs specific activity.

A statistically significant correlation was observed between urinary iodine content and serum FT_4 and TSH levels, but all of the estimated correlation coefficients were small.

Two cases of thyroid papillary cancer were registered (Belynichskii and Cherikovskii Rayons). Surgery was performed and the children are under the observation of an endocrinologist.

Hematological studies

The hematological deviations are characterized by the quantitative and qualitative status.

The medians of the parameters in the hemograms were in the range of the expected age limits. In estimating eosinophil count, the deviations from the normal range in the hemogram were more pronounced in the following rayons: Krichevskii (^{137}Cs contamination level is in the range of 0.10–8.90 Ci/km^2), Klimovichskii (0.04–41.83 Ci/km^2), Cherikovskii (0.01–65.67 Ci/km^2) and Slavgorodskii (0.01–49.43 Ci/km^2) Rayons.

An increasing trend in the number of children with hematological abnormalities such as eosinophilia, neutrophilia and lymphopenia was observed with an increase in a ^{137}Cs specific activity level. But most of these abnormalities were transient.

The assays of serum ferritin are importance for differential diagnosis of cases with anemia.

The following diseases were found: 1 case of lymphogranulomatosis (Hodgkin's disease); 2 cases of thrombocytopenic purpura (Werlhof's disease); and 3 cases of the Pelger anomaly of neutrophils.

Conclusions

The results of the four-year investigation show clearly that the data obtained are of enormous scientific value. They are particularly important for each individual child because the examinations allow us to establish early diagnoses and to start a course of treatment in due time.

Results of the Examination of the Health Status of Children in Gomel Oblast 1991–1994 Chernobyl Sasakawa Project

Gomel Specialized Medical Dispensary
Radiation Medicine Center

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1. Introduction

The ecological situation in Gomel Oblast deteriorated dramatically after the accident at the Chernobyl Nuclear Power Station, and the level of morbidity among the population significantly increased. Analyses of the morbidity over the past few years have drawn close attention to the disorders determined. The increase in these disorders may be attributable to the effects of radiation.

Under these conditions, a long-term program for medical examinations and the health studies for the children of Gomel Oblast on the basis of the Chernobyl Sasakawa Project is of inestimable importance. This program was initiated by the Sasakawa Memorial Health Foundation and began operating in May 1991. The program is financed mainly by the Foundation and enjoys the participation of prominent Japanese scientists.

An investigation has been carried out for four years on the health status of children residing in Gomel Oblast. The program is implemented in accordance with the Chernobyl Sasakawa Project and provides a conceptual basis for preventive measures directed towards the treatment and health improvement of the children.

A total of 18,328 children were examined by the staff of the dispensary during the period from May 1991 to December 31, 1994. Among these, 14,054 were born in the period from April 26, 1976 to April 26, 1986 and underwent a thorough examination. We used this group for the analysis of the investigation results.

To examine the children, a mobile diagnostic laboratory donated by the Sasakawa Foundation was dispatched to the places of residence. The laboratory is equipped with facilities for dosimetry, ultrasonography and laboratory analyses. The examination of children was carried out by skilled staff. Individual groups of children were also examined directly at the specialized dispensary using a set of stationary medical equipment donated by the Sasakawa Foundation.

2. Materials and Methods

2.1 Study subjects

Children residing in areas with a ^{137}Cs contamination density over 1 Ci/km^2 and those resettled from zones deemed dangerous for living were chosen for examination. The children under examination live in settlements in the Braginskii, Buda-Koshelevskii, Vetkovskii, Gomelskii, Dobrushskii, Elskii, Zitkovichskii, Zlobinskii, Kalinkovichskii Kormyanskii, Lelchitskii, Loevskii, Mozirskii, Narovlyanskii, Oktyabrskii, Petrikovskii, Rechitskii, Rogachevskii, Svetlogorskii, Hoynikskii and Checherskii Rayons and also in the cities of Gomel and Mozir.

The information was analyzed for the oblast as a whole and for each individual rayon. The results were analyzed for the whole population regardless of sex and also for boys and girls grouped separately according to age.

Figure 1 shows the ^{137}Cs contamination levels (Ci/km^2) including the extreme values for all rayons of Gomel Oblast.

2.2 Measurement of whole body ^{137}Cs concentration

To determine whole body ^{137}Cs concentration, we used a gamma-spectrometer Model-101 equipped with a collimator manufactured by the Aloka Company. The results of measurements were processed using the software installed in the computer.

Energetic calibration of the gamma-spectrometer with a standard source of ^{137}Cs and ^{60}Co was performed first. This procedure facilitated the estimation of errors

Figure 1. ^{137}Cs contamination levels (Ci/km^2) in the rayons of Gomel Oblast as measured in 1992.

[a] The triplets give the 25th, 50th and 75th sample percentiles of contamination levels.

[b] Minimum and maximum levels of contamination.

caused by varying the parameters of the spectrometer amplifier and thus promoted the achievement of steady results. Measurement of external background without phantom was conducted next. To correct the results of measurement of body gamma-radiation, the value of the external background was subtracted from the readings of the unit. The next step was the measurement of radiation background in phantoms made from Lucite plates of 5, 10, 15 and 20 cm in thickness.

After these preparatory procedures, the whole body ^{137}Cs concentration of the subjects was measured. The subject sits in front of the collimator while the operator inputs personal data such as body weight, height, size of chest and then performs the measurement. The results of these measurements are stored in the computer and printed.

2.3 Thyroid examinations

The thorough examination of the thyroid gland consists of an ultrasound examination, determination of the circulating levels of thyroid stimulating hormone (TSH) and free T_4 (FT_4), titers of anti-thyroglobulin antibody (ATG) and anti-microsome antibody (AMC). Children with any deviation from the normal limits were then examined by an endocrinologist.

Ultrasound examinations were performed with an Aloka SSD-520 and Aloka-630. A quantitative and qualitative analysis of the state of the thyroid and surrounding tissues, blood vessels and lymph nodes was carried out. Using an arch-automatic ultrasonographic instrument, we examined thyroid volume, position, structure, echogenity and the presence of abnormal structures such as nodules, cysts and anomalies. Fine needle aspiration biopsy was performed to confirm the diagnoses in children with abnormal findings of thyroid images.

The functional state of the thyroid (FT_4 and TSH) was studied by the immunometric technique using an Amerlite unit (Amersham Company). Diagnostic kits produced by the same company were used to determine FT_4 and TSH.

The titers of AMC and ATG antibodies were determined visually by the reaction of passive hemagglutination using diagnostic kits provided by the Fujirevo Company.

These techniques are the main criteria for establishing clinical diagnoses of thyroid diseases.

2.4 Hematological studies

Hematological tests were carried out for the following 8 parameters: (1) white blood cell count (WBC); (2) red blood cell count (RBC); (3) platelet count (PLT); (4) hemoglobin concentration (Hb); (5) hematocrit (Ht); (6) mean corpuscular volume (MCV); (7) mean corpuscular hemoglobin (MCH); and (8) mean corpuscular hemoglobin concentration (MCHC).

Blood testing was conducted with Sysmex K-1000 and Sysmex NE-7000 hemoanalyzers. Special EK-0205 vacuum tubes were used for blood sampling. The differential leukocyte count in stained smears was analyzed with an Olympus-BH-2 microscope.

3. Results

3.1 Study subjects

The results of the examination of 14,396 children (6,927 boys and 7,469 girls) were analyzed. Table 1 shows the number of children examined by age and sex along with the 25th, 50th and 75th percentiles for each rayon and for the oblast as a whole. The Zitkovichskii and Narovlyanskii Rayons were excluded from the table because the examined subjects were less than 10.

3.2 Measurement of whole body ^{137}Cs concentration

Figure 2 shows the distribution of ^{137}Cs content level per kg body weight (Bq/kg) by sex and age among children examined in 1994. The children with whole body ^{137}Cs count less than the detection limit, i.e. 540 Bq, were excluded from the figure. The number of boys and girls excluded in each age group was as follows (girls in parentheses): 7-year, 5(4); 8-year, 47(90); 9-year, 44(55); 10-year, 28(32); 11-year, 15(27); 12-year, 8(12); 13-year, 1(12); 14-year, 1(3); and 15-year, 0(1). The data obtained were virtually the same as those in 1993. There was no essential difference in the specific ^{137}Cs concentration level in either boys or girls under 10 years old. In the group of children from 11 to 15 years old, the accumulation of ^{137}Cs was higher in boys than in girls of the same age.

Figure 3 shows the data on the distribution of ^{137}Cs specific concentration in the body by place of residence among children examined from 1991 to 1994. The number of children excluded from the figure having whole body ^{137}Cs count less than 540 Bq was as follows: 2 in Braginskii; 2 in Buda-Koshelevskii; 3 in Vetkovskii; 188 in Gomelskii; 1 in Dobrushskii; 37 in Zlobinskii; 4 in Loevskii; 1 in Oktyabrskii; 47 in Rechitskii; 19 in Rogachevskii; 1 in Svetlogorskii; 3 in Hoynikskii; 1 in Checherskii Rayons; 75 in Gomel City; and 1 in Mozir City. The medians of the incorporated ^{137}Cs activity were in the range of 30–140 Bq/kg. The highest levels were registered in the Braginskii, Kormyanskii, Lelchitskii, Elskii and Vetkovskii Rayons (140, 116, 83, 83 and 81 Bq/kg, respectively). The level was not higher than 50 Bq/kg in the remaining 14 rayons. It is logical that the highest levels were noted in the rayons affected most severely by the Chernobyl accident (Braginskii, Vetkovskii and Kormyanskii Rayons) and also in the territories included in the radioecological anomaly zone of the Belarus-Ukraine Polessye (Lelchitskii and Elskii Rayons) where coefficients of proportionality in soil-vegetation ratio are 3–10 times higher than those found outside the Polessye zone boundaries. An analysis of dynamics of the ^{137}Cs content in the body of children repeatedly examined in the period from 1991 to 1994 shows that a significant decrease in ^{137}Cs incorporated activity was observed only in 1991–1992. At the present time, the decrease in mean values of ^{137}Cs concentration in the body of children does not exceed 5–10% per year as a result of the stabilized radiation situation and the implementation of measures for radiation protection of the population. This is clearly evident if we compare the 1993 and 1994 data from Gomelskii, Zlobinskii, Rechitskii and Rogachevskii Rayons. Only 17 boys (0.25%) and 11 girls (0.15%) showed ^{137}Cs accumulation levels over 500 Bq/kg.

Table 1. Classification of study subjects by sex and place of residence.[a]

Place of residence	Boys	Girls	Total
Braginskii	332 (8, 10, 12)	306 (8, 10, 12)	638 (8, 10, 12)
Buda-Koshelevski	160 (8, 10, 13)	203 (8, 11, 13)	363 (8, 10, 13)
Vetkovskii	25 (9, 11, 12)	28 (9, 11, 12)	53 (9, 11, 12)
Gomelskii	2395 (9, 11, 13)	2460 (9, 11, 13)	4855 (9, 11, 13)
Dobrushskii	548 (7, 9, 11)	626 (7, 9, 11)	1174 (7, 9, 11)
Elskii	142 (7, 9, 12)	201 (7, 10, 12)	343 (7, 10, 12)
Zlobinskii	217 (9, 11, 13)	281 (9, 11, 13)	498 (9, 11, 13)
Kalinkovichskii	20 (8, 11, 12)	23 (11, 12, 13)	43 (10, 11, 13)
Kormyanskii	55 (7, 8, 9)	57 (7, 8, 10)	112 (7, 8, 10)
Lelchitskii	26 (6, 8, 10)	58 (8, 10, 12)	84 (6, 9, 11)
Loevskii	295 (7, 9, 12)	268 (8, 10, 12)	563 (7, 10, 12)
Mozirskii	4 (7, 13, 14)	13 (8, 10, 10)	17 (8, 10, 11)
Oktyabrskii	10 (8, 9, 12)	18 (10, 12, 13)	28 (8, 11, 13)
Petrikovskii	72 (7, 10, 12)	108 (6, 9, 12)	180 (7, 9, 12)
Rechitskii	808 (9, 11, 13)	820 (9, 11, 13)	1628 (9, 11, 13)
Rogachevskii	311 (9, 11, 13)	359 (9, 11, 13)	670 (9, 11, 13)
Svetlogorskii	24 (8, 11, 13)	30 (11, 13, 17)	54 (10, 12, 14)
Hoynikskii	172 (8, 10, 13)	157 (9, 10, 13)	329 (8, 10, 13)
Checherskii	35 (10, 12, 14)	48 (9, 10, 13)	83 (9, 12, 13)
Gomel City	1243 (8, 10, 12)	1368 (8, 10, 12)	2611 (8, 10, 12)
Mozir City	33 (8, 9, 11)	37 (9, 10, 11)	70 (8, 10, 11)
Total	6927 (8, 10, 12)	7469 (8, 10, 13)	14 396 (8, 10, 12)

[a] Each triplet gives the 25th, 50th and 75th sample percentiles of age distribution at the time of examination.

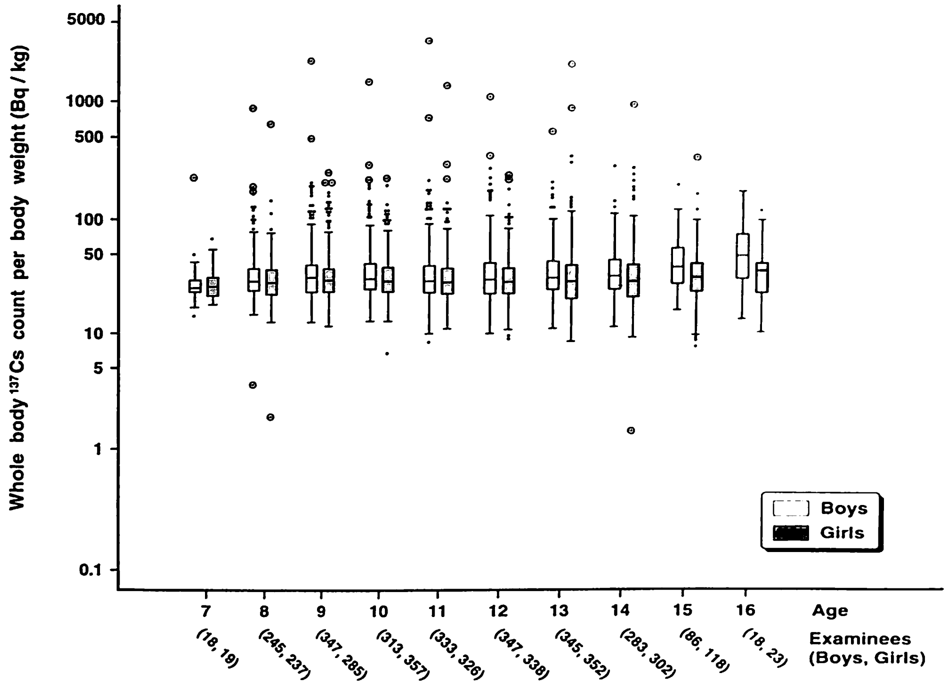

Figure 2. The box-and-whisker plots of whole body ^{137}Cs count per kg body weight by sex and age among children examined in 1994. The children with whole body ^{137}Cs count less than the detection limit (540 Bq) were excluded. The bottom and top ends of the box and the bar inside the box correspond to the 25th, 75th and 50th sample percentiles, respectively. The black dot and the double circle with black dot represent extreme values, called "outside" and "far out," respectively.

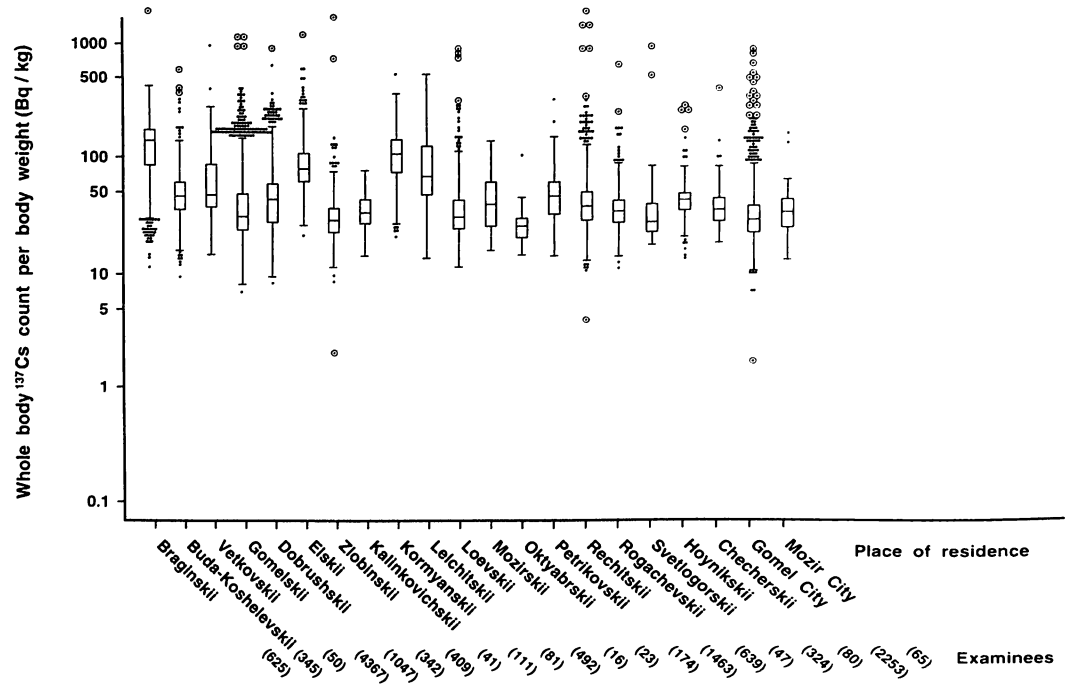

Figure 3. The box-and-whisker plots of whole body ^{137}Cs count per kg body weight by place of residence among children examined from 1991 to 1994. The children with whole body ^{137}Cs count less than the detection limit (540 Bq) were excluded. See Figure 2 for details.

3.3 Thyroid examinations

Figure 4 showing the distribution of the thyroid volume by sex and age indicates that: (1) the thyroid volume increased with age in both boys and girls; (2) the thyroid volume increased particularly from the start of puberty (girls-11 years old, boys-12 years old). It should be noted that the girls were found to show a higher increase in thyroid volume than boys under 14 years of age; and (3) the thyroid volume reached a peak in girls from the age of 15 and in boys from the age of 16.

Figure 5 shows the prevalence of goiter by place of residence. The prevalence of goiter was obviously higher in girls than in boys. The largest number of goiter cases was noted in the Rechitskii Rayon, which was screened in 1994.

Figures 6 and 7 show the prevalence of goiter by sex in relation to the soil ^{137}Cs contamination level in the place of stay and the place of residence at the time of the accident, respectively. No significant relationship was observed between the contamination level and prevalence of goiter.

Figure 8 shows the prevalence of goiter in relation to the ^{137}Cs concentration in the bodies of boys and girls. No significant relationship could be established.

Figures 9 and 10 show the prevalence of positive ATG and AMC titers in girls and boys relative to the incorporated ^{137}Cs concentration. No relationship was observed between the prevalence of positive titers of antibodies and specific ^{137}Cs concentration.

Figures 11–14 show the prevalence of positive titers of ATG and AMC antibodies in girls and boys in relation to the contamination level in the place of residence at the time of the accident and current residence. No relationship could be established be-

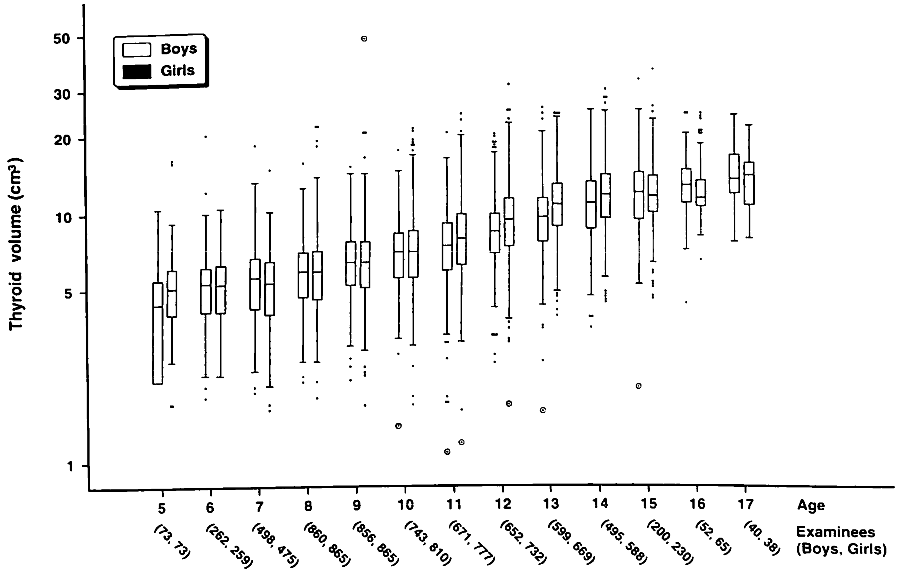

Figure 4. The box-and-whisker plots of thyroid volume by sex and age. See Figure 2 for details.

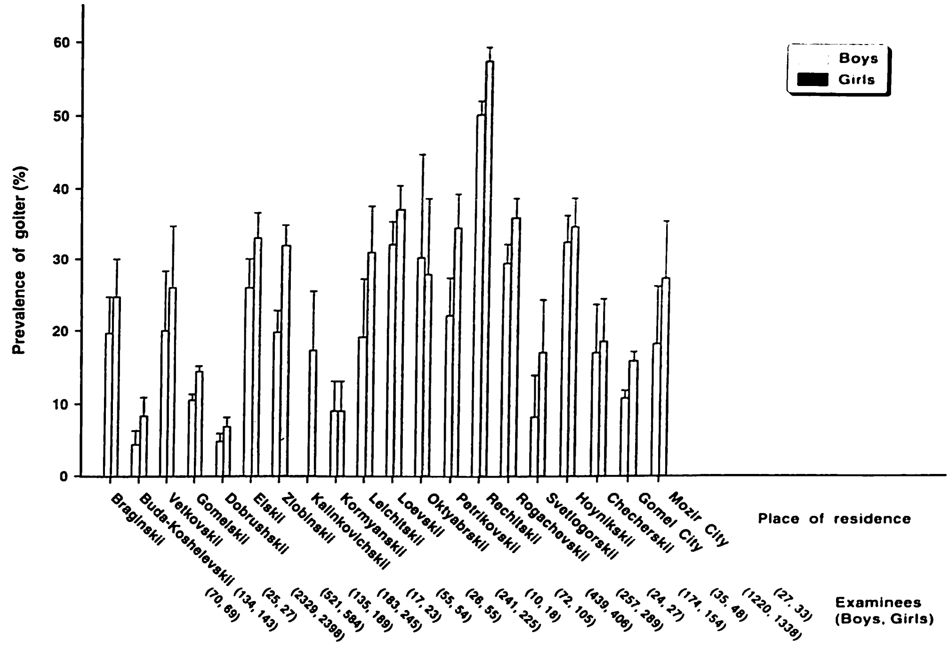

Figure 5. Prevalence of goiter by sex and place of current residence. The whiskers denote the standard errors. See page 2 for the definition of goiter.

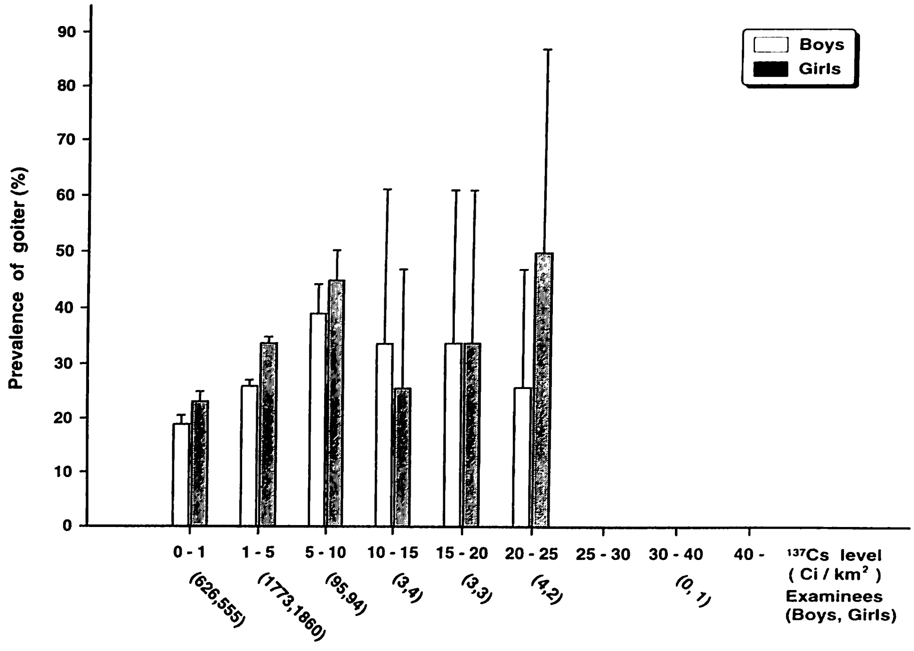

Figure 6. Prevalence of goiter by sex and contamination level (Ci/km^2) in the place of current residence. The whiskers denote the standard errors. See page 2 for the definition of goiter.

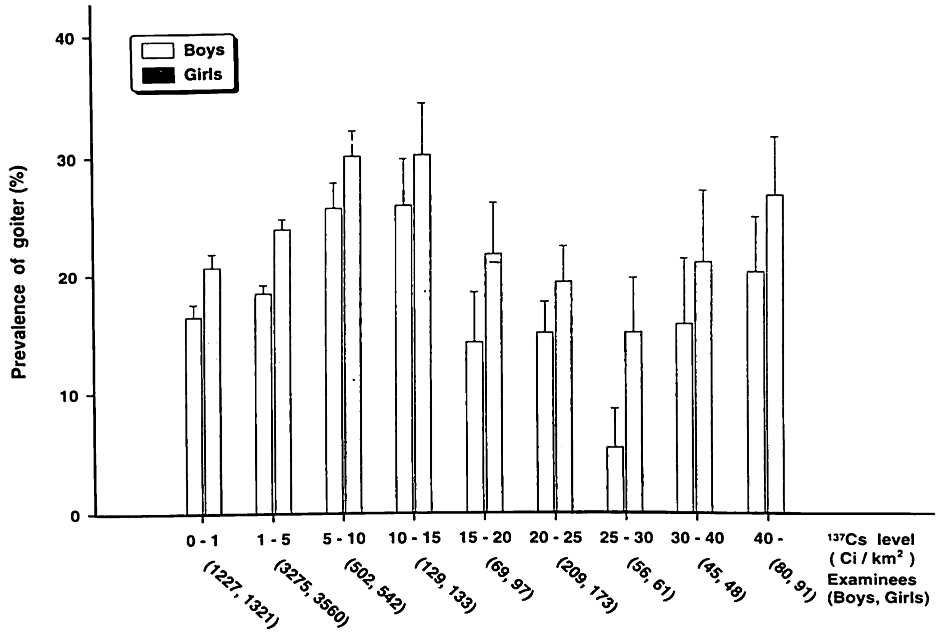

Figure 7. Prevalence of goiter by sex and contamination level (Ci/km^2) in the place of residence at the time of the accident. The whiskers denote the standard errors. See page 2 for the definition of goiter.

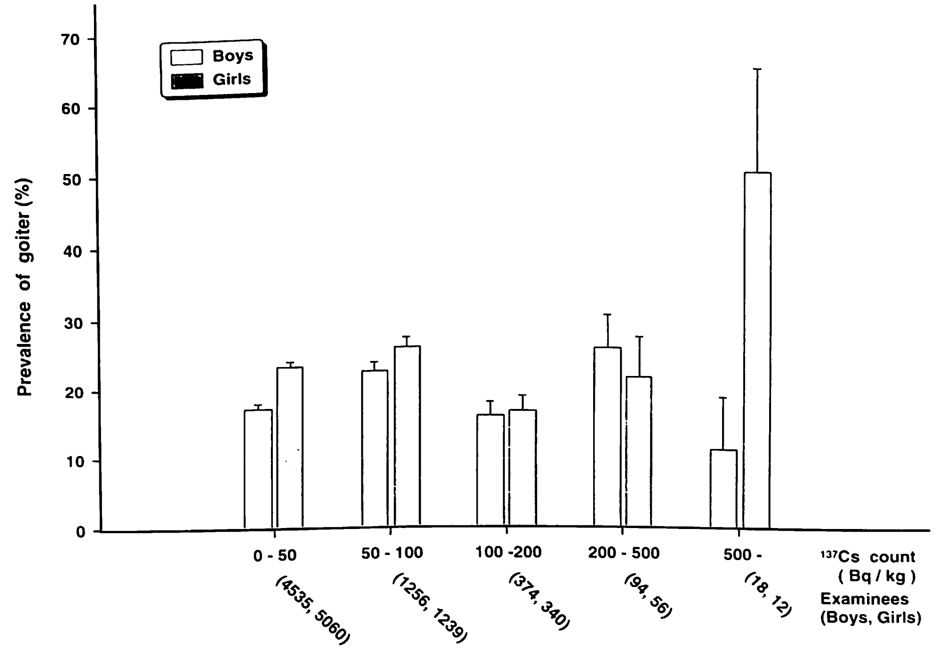

Figure 8. Prevalence of goiter by sex and whole body ^{137}Cs count per kg body weight. The whiskers denote the standard errors. See page 2 for the definition of goiter.

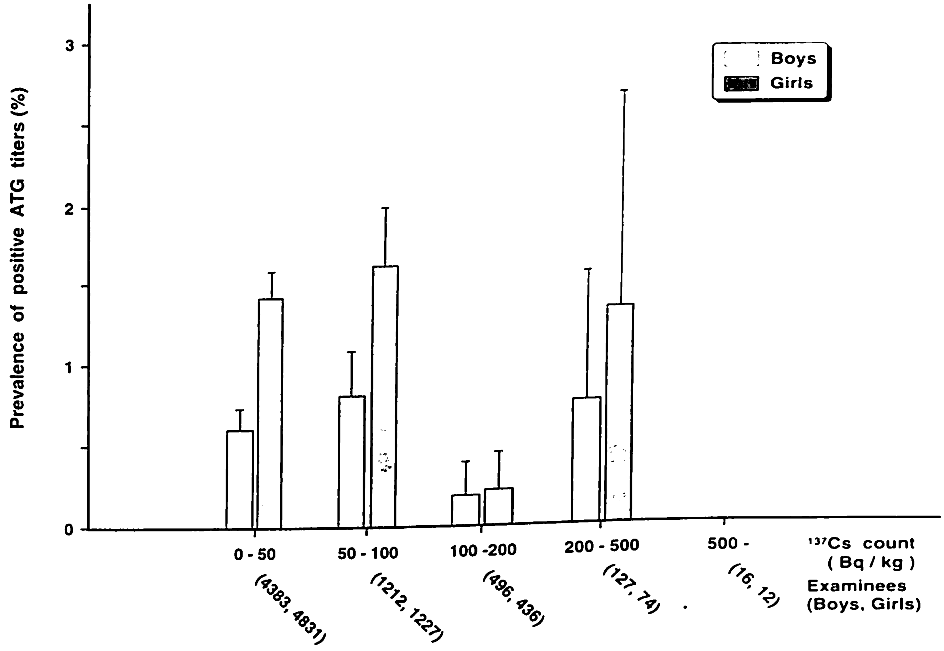

Figure 9. Prevalence of positive ATG titers by sex and whole body ^{137}Cs count per kg body weight. The whiskers denote the standard errors.

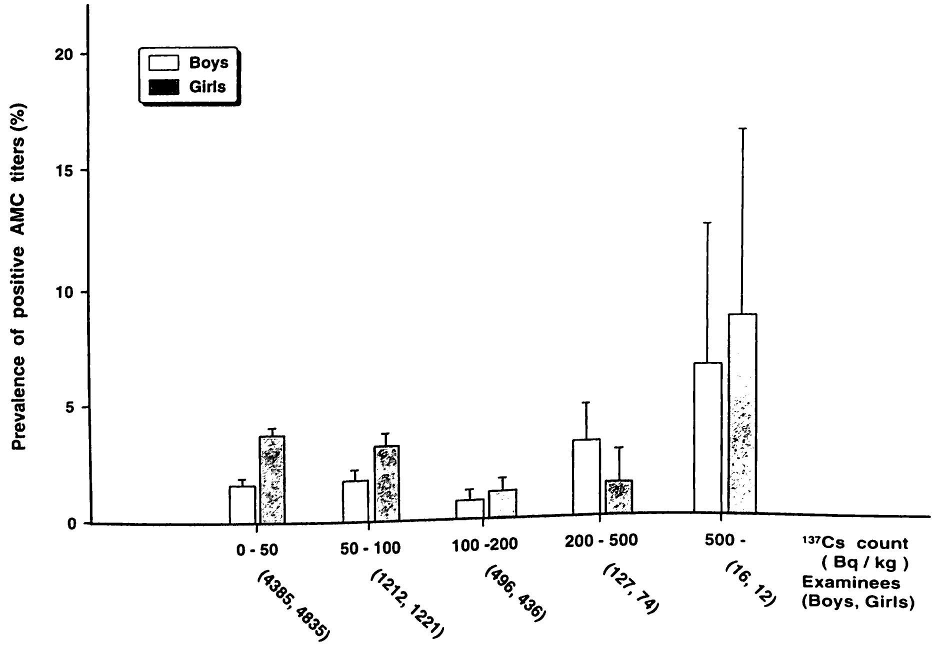

Figure 10. Prevalence of positive AMC titers by sex and whole body ^{137}Cs count per kg body weight. The whiskers denote the standard errors.

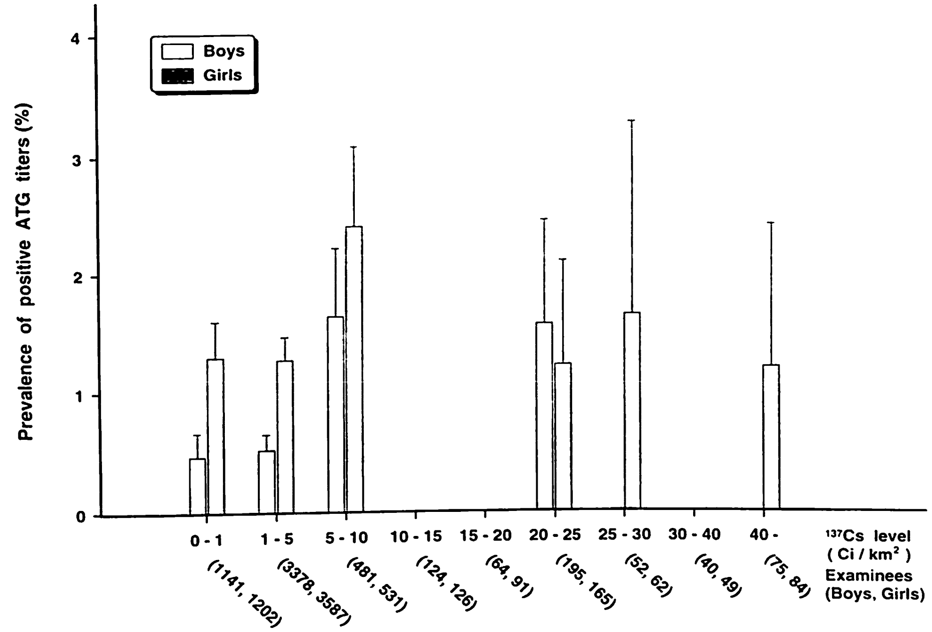

Figure 11. Prevalence of positive ATG titers by sex and contamination level (Ci/km^2) in the place of residence at the time of the accident. The whiskers denote the standard errors.

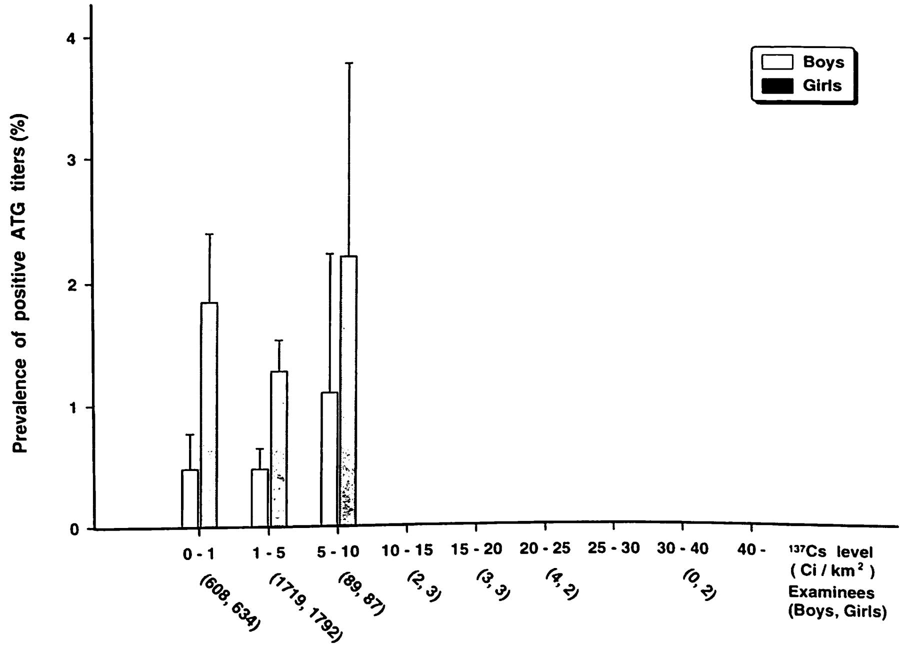

Figure 12. Prevalence of positive ATG titers by sex and contamination level (Ci/km^2) in the place of current residence. The whiskers denote the standard errors.

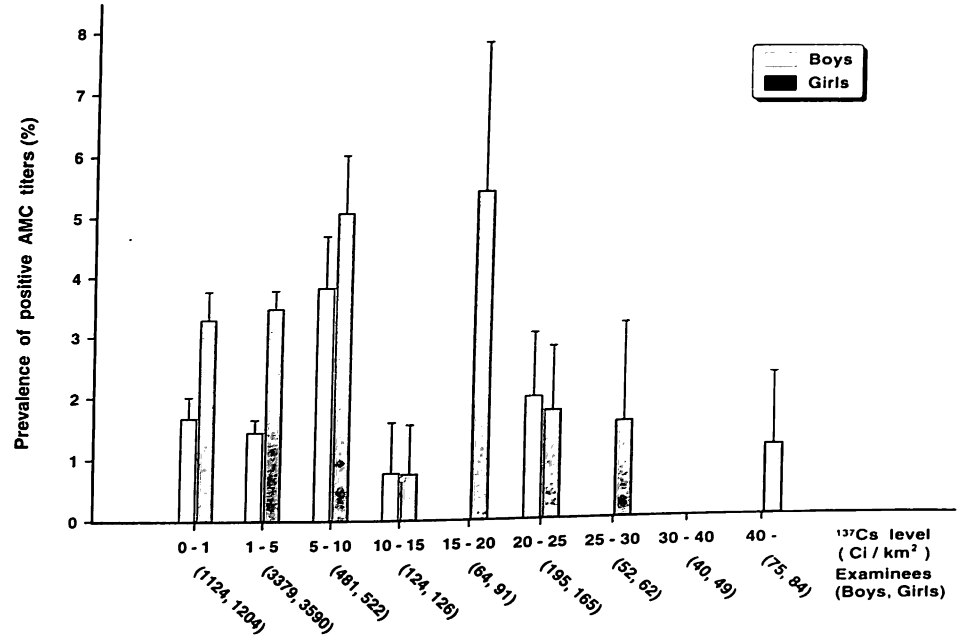

Figure 13. Prevalence of positive AMC titers by sex and contamination level (Ci/km^2) in the place of residence at the time of the accident. The whiskers denote the standard errors.

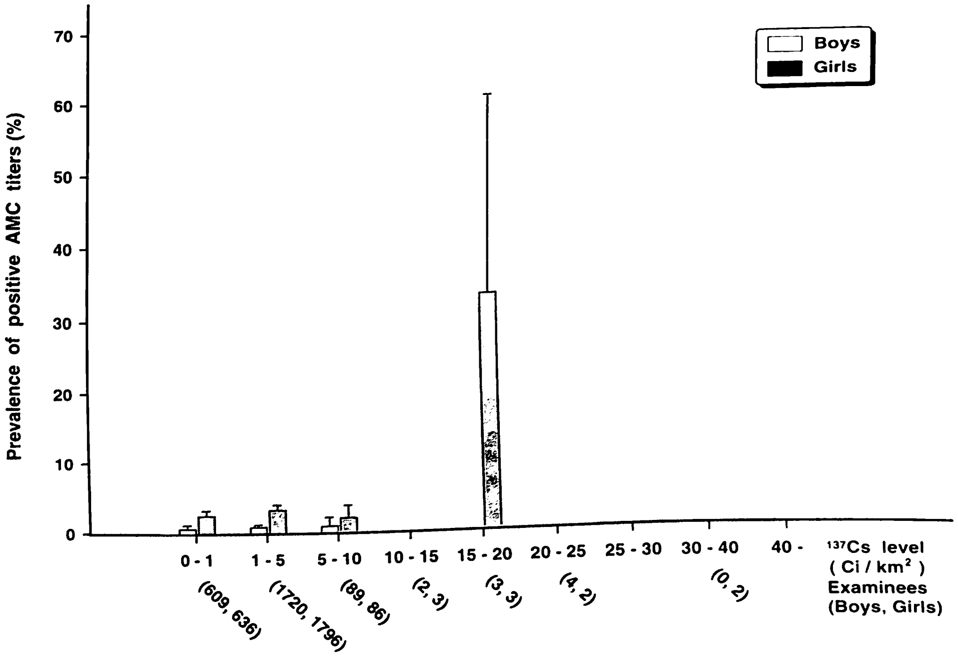

Figure 14. Prevalence of positive AMC titers by sex and contamination level (Ci/km^2) in the place of current residence. The whiskers denote the standard errors.

tween the ^{137}Cs concentration level and the prevalence of positive titers of ATG and AMC antibodies.

Table 2 shows subjects with thyroid abnormalities by sex and place of residence. We analyzed the data from the table. The largest number of children with nodular lesions and decreased echogenity was found in Rechitskii and Gomelskii Rayons, including Gomel City.

Table 3 shows the total number of children first examined by sex and place of residence including positive titers of ATG and AMC antibodies. From Table 3 it may be concluded that: (1) positive AMC titers were 3 times as frequent as positive ATG titers; (2) the highest percentage of children with positive AMC and ATG titers was noted in Elskii, Hoynikskii Rayons and in Gomel City, where sufficient statistical data were available; and (3) the prevalence of positive AMC and ATG titers was twice as high in girls as in boys. The total number of children with positive ATG and AMC titers amounted to 129 (0.9%) and 335 (2.4%), respectively.

Table 4 shows the quantitative distribution by sex and place of residence of children with a high level of TSH and low level of FT_4 (hypothyroidism) and a low level of TSH and high level of FT_4 (hyperthyroidism).

Table 2. Subjects with thyroid abnormalities by sex and place of residence.

Place of residence	Number of subjects examined		Diagnosis									
			Nodular lesion		Cystic lesion		Abnormal echogenity		Anomaly		Cancer	
	B[a]	G[a]	B	G	B	G	B	G	B	G	B	G
Braginskii	315	300	1	2	0	0	2	5	0	1	1	2
Buda-Koshelevskii	162	201	5	3	0	0	0	4	1	1	1	2
Vetkovskii	26	26	0	0	0	2	0	4	0	0	0	0
Gomelskii	2319	2376	38	65	4	8	92	132	6	7	0	3
Dobrushskii	568	644	4	4	0	0	3	7	0	0	0	1
Elskii	141	201	0	0	0	0	0	4	0	0	0	0
Zlobinskii	194	262	2	9	0	1	7	12	2	2	0	0
Kalinkovichskii	21	24	0	0	0	0	0	1	0	0	0	0
Kormyanskii	57	58	1	1	0	0	1	2	0	1	1	0
Lelchitskii	26	58	2	1	0	0	1	4	0	0	0	1
Loevskii	301	273	3	5	3	0	6	2	0	1	0	0
Mozirskii	11	26	1	3	0	0	2	6	0	0	0	0
Oktyabrskii	10	18	0	0	0	0	1	1	0	0	0	0
Petrikovskii	70	109	1	0	0	0	0	6	0	0	0	0
Rechitskii	733	742	6	18	7	7	36	57	1	1	0	1
Rogachevskii	300	343	1	2	1	1	16	26	1	1	0	1
Svetlogorskii	21	30	0	1	0	0	0	1	0	0	0	0
Hoynikskii	175	159	1	0	1	0	0	2	2	0	1	0
Checherskii	35	47	0	0	0	0	0	0	0	0	0	0
Gomel City	1260	1367	21	53	11	9	34	92	6	17	2	6
Mozir City	25	24	2	2	1	0	0	6	0	2	0	0
Total	6766	7288	89	169	28	28	201	374	19	34	6	17

[a] B, boys, G, girls

Table 3. Prevalence of positive ATG (anti-thyroglobulin antibody) and AMC (anti-microsome antibody) titers by sex and place of residence.[a]

Place of residence	Number of subjects measured			Antibody					
				Anti-thyroglobulin			Anti-microsome		
	Total	Boys	Girls	Total	Boys	Girls	Total	Boys	Girls
Braginskii	400	218	182	6 (1.5)	3 (1.4)	3 (1.6)	8 (2.0)	3 (1.4)	5 (2.7)
Buda-Koshelevskii	228	95	133	2 (0.9)	1 (1.0)	1 (0.8)	6 (2.6)	3 (3.2)	3 (2.3)
Vetkovskii	51	24	27	2 (3.9)	1 (4.2)	1 (3.7)	5 (9.8)	1 (4.2)	4 (14.8)
Gomelskii	4606	2286	2320	28 (0.6)	7 (0.3)	21 (0.9)	79 (1.7)	25 (1.1)	54 (2.3)
Dobrushskii	1012	476	536	14 (1.4)	5 (1.1)	9 (1.7)	33 (3.3)	12 (2.5)	21 (3.9)
Elskii	315	132	183	9 (2.9)	2 (1.5)	7 (3.8)	27 (8.6)	10 (7.6)	17 (9.3)
Zitkovichskii	3	1	2	0	0	0	0	0	0
Zlobinskii	492	211	281	2 (0.4)	1 (0.5)	1 (0.4)	4 (0.8)	3 (1.4)	1 (0.4)
Kalinkovichskii	38	17	21	0	0	0	1 (2.6)	0	1 (4.8)
Kormyanskii	108	52	56	0	0	0	1 (0.9)	0	1 (1.8)
Lelchitskii	76	21	55	0	0	0	2 (2.6)	0	2 (3.6)
Loevskii	526	278	248	4 (0.8)	1 (0.4)	3 (1.2)	13 (2.5)	4 (1.4)	9 (3.6)
Mozirskii	14	4	10	1 (7.1)	0	1 (10.0)	1 (7.1)	0	1 (10.0)
Narovlyanskii	3	2	1	0	0	0	0	0	0
Oktyabrskii	14	4	10	0	0	0	1 (7.1)	0	1 (10.0)
Petrikovskii	170	68	102	2 (1.2)	0	2 (2.0)	2 (1.2)	0	2 (2.0)
Rechitskii	1576	785	791	15 (1.0)	4 (0.5)	11 (1.4)	25 (1.6)	5 (0.6)	20 (2.5)
Rogachevskii	658	306	352	4 (0.6)	2 (0.7)	2 (0.6)	7 (1.1)	3 (1.0)	4 (1.1)
Svetlogorskii	51	22	29	1 (2.0)	0	1 (3.4)	1 (2.0)	0	1 (3.4)
Hoynikskii	319	167	152	6 (1.9)	3 (1.8)	3 (2.0)	10 (3.1)	5 (3.0)	5 (3.3)
Checherskii	51	23	28	0	0	0	1 (2.3)	1 (4.3)	0
Gomel City	2429	1168	1261	36 (1.5)	10 (0.9)	26 (2.1)	116 (4.8)	31 (2.7)	85 (6.7)
Mozir City	66	30	36	2 (3.0)	0	2 (5.6)	4 (6.1)	1 (3.3)	3 (8.3)
Total	13 206	6390	6816	134 (1.0)	40 (0.6)	94 (1.4)	347 (2.6)	107 (1.7)	240 (3.5)

[a] Number of subjects with percentages in parentheses.

Table 4. Number of subjects with hypothyroidism and hyperthyroidism by sex and place of residence.

Place of residence	Number of subjects with measurement			Hypothyroidism[a]			Hyperthyroidism[b]		
	Total	Boys	Girls	Total	Boys	Girls	Total	Boys	Girls
Braginskii	427	232	195	1	1	0	1	0	1
Buda-Koshelevskii	233	96	137	1	0	1	1	1	0
Vetkovskii	53	25	28	0	0	0	0	0	0
Gomelskii	4608	2288	2320	14	4	10	6	2	4
Dobrushskii	1011	475	536	4	1	3	1	0	1
Elskii	231	92	139	1	0	1	0	0	0
Zitkovichskii	3	1	2	0	0	0	0	0	0
Zlobinskii	493	212	281	0	0	0	4	2	2
Kalinkovichskii	38	17	21	1	0	1	0	0	0
Kormyanskii	110	53	57	1	1	0	0	0	0
Lelchitskii	77	22	55	0	0	0	1	0	1
Loevskii	541	284	257	4	2	2	1	1	0
Mozirskii	15	4	11	0	0	0	0	0	0
Narovlyanskii	3	2	1	0	0	0	0	0	0
Oktyabrskii	28	10	18	0	0	0	0	0	0
Petrikovskii	176	72	104	2	1	1	0	0	0
Rechitskii	1578	786	792	4	0	4	2	0	2
Rogachevskii	658	305	353	0	0	0	1	0	1
Svetlogorskii	52	22	30	0	0	0	0	0	0
Hoynikskii	319	167	152	1	1	0	0	0	0
Checherskii	52	23	29	0	0	0	0	0	0
Gomel City	2488	1192	1296	6	4	2	6	2	4
Mozir City	66	30	36	0	0	0	0	0	0
Total	13 260	6410	6850	40	15	25	24	8	16

[a] Diagnosed when free $T_4 < 10.0$ pmol/L and TSH > 2.90 μIU/mL.

[b] Diagnosed when free $T_4 > 25.0$ pmol/L and TSH < 0.24 μIU/mL.

Figures 15–17 show the correlation between urinary iodine excretion and the following items: free T_4, TSH and residual thyroid volume. All of the estimated correlation coefficients were very small and no correlation was observed between urinary iodine content and FT_4 level, residual thyroid volume or TSH level. Children with cancer who received replacement therapy for thyroid hormones were excluded for verification of the data.

We have analyzed all tables and plots for thyroid abnormalities. The largest number of thyroid abnormalities was observed in Rechitskii Rayon in spite of the fact that this rayon is considered relatively "non-contaminated" (the median of the ^{137}Cs contamination density is 1.5 Ci/km^2). It is no mere coincidence from our point of view. The rayon was exposed to radioactive iodine fallout shortly after the accident at the Chernobyl Nuclear Power Station, and the doses in children and teenagers could be compared with those of the resettled inhabitants from the southern rayons of Gomel Oblast.

In the period from May 1991 to December 1994 we diagnosed 23 cases of thyroid

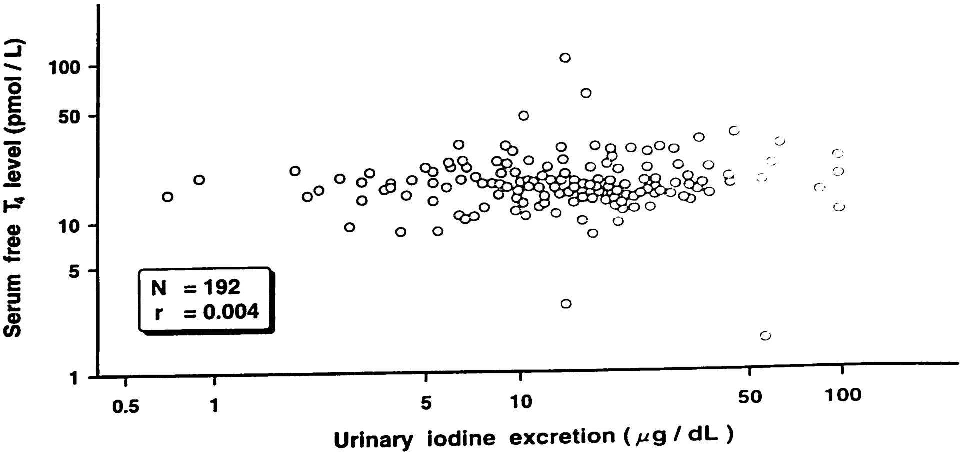

Figure 15. Scatter plots of urinary iodine excretion and serum free T_4 level.

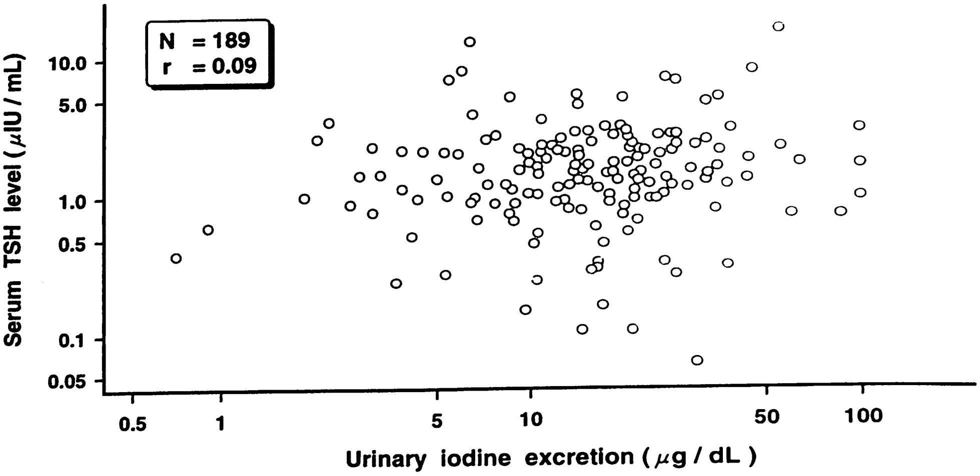

Figure 16. Scatter plots of urinary iodine excretion and serum TSH level.

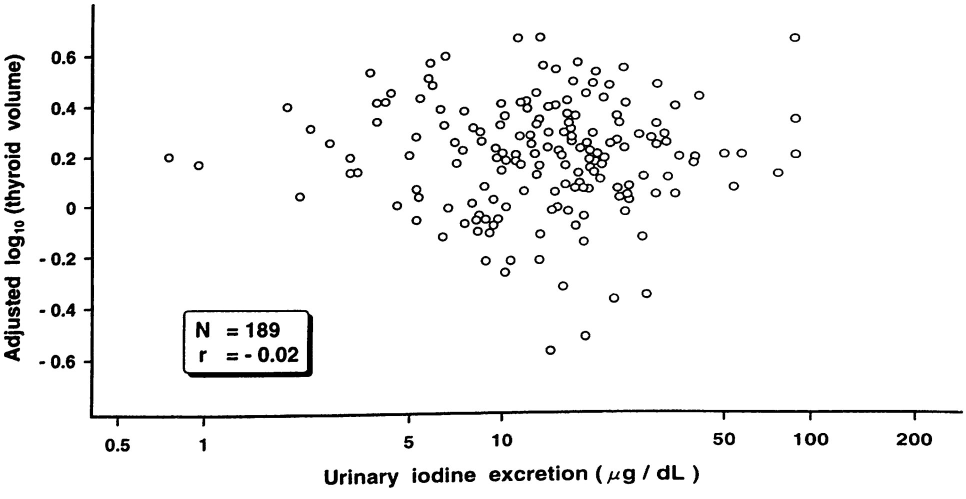

Figure 17. Scatter plots of urinary iodine excretion and the residual of the logarithm of thyroid volume after adjustment for age, height and weight.

carcinoma in the course of the Sasakawa Project: 6 boys and 17 girls. Eight cases were found in Gomel City, 3 each in Braginskii, Buda-Koshelevskii, and Gomelskii Rayons, and 1 each in Dobrushskii, Kormyanskii, Lelchitskii, Rechitskii, Rogachevskii and Hoynikskii Rayons. Histologically, all of these cases were papillary carcinoma.

A total of 88 autoimmune thyroiditis cases (13 boys and 75 girls) were diagnosed in the period from May 1991 to December 1994.

3.4 Hematological studies

A total of 14,396 hematological tests were carried out but only 10,179 analyses included leukocyte differential count since this test was not introduced until the middle of 1992.

Figure 18 shows the relationship between Hb level and age and sex. The median level was within the normal range. The Hb level was higher in boys than in girls in all age groups. Hb level increased with age in both boys and girls. It levelled off in girls aged 12–14 years old and then showed a slight decrease at the age of 15–17.

The initial examinations showed 74 cases with reduced Hb (< 110 g/L). Of the 59 re-examined, 38 children were found to have iron deficiency anemia. The diagnosis was established on the basis of general blood count and additional investigations including the measurement of serum iron and ferritin levels. One girl (41 g/L Hb level) showed acute leukemia, but 20 children in the same group were found to have a normal Hb level at re-examination.

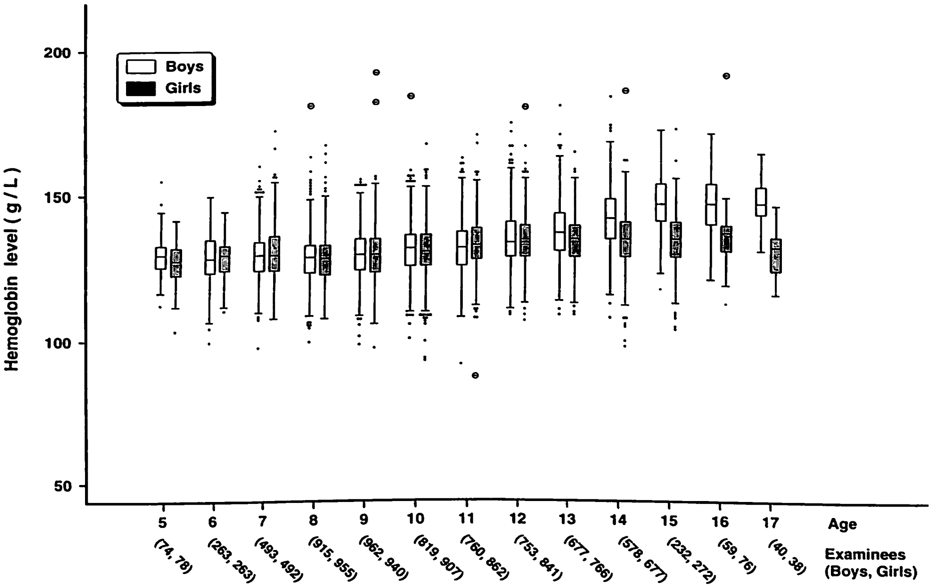

Figure 18. The box-and-whisker plots of hemoglobin level by sex and age. See Figure 2 for details.

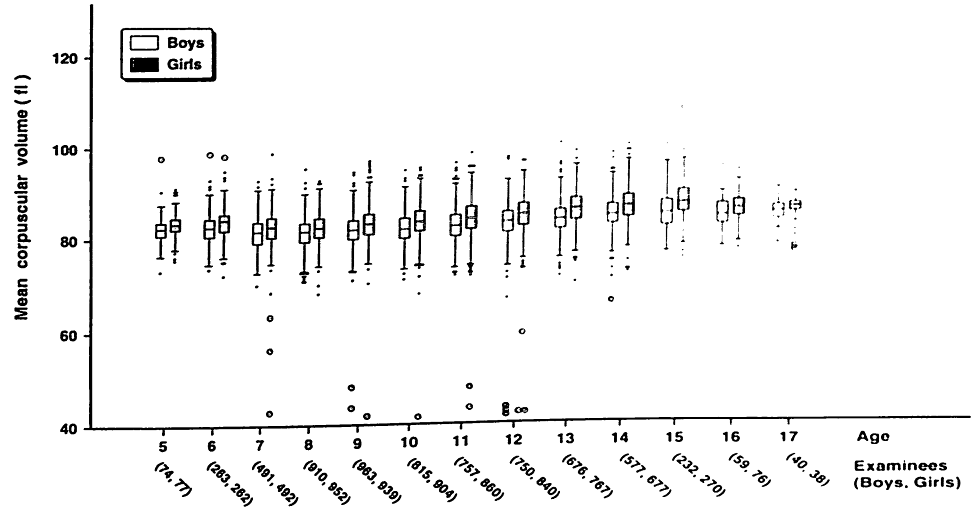

Figure 19. The box-and-whisker plots of mean corpuscular volume by sex and age. See Figure 2 for details.

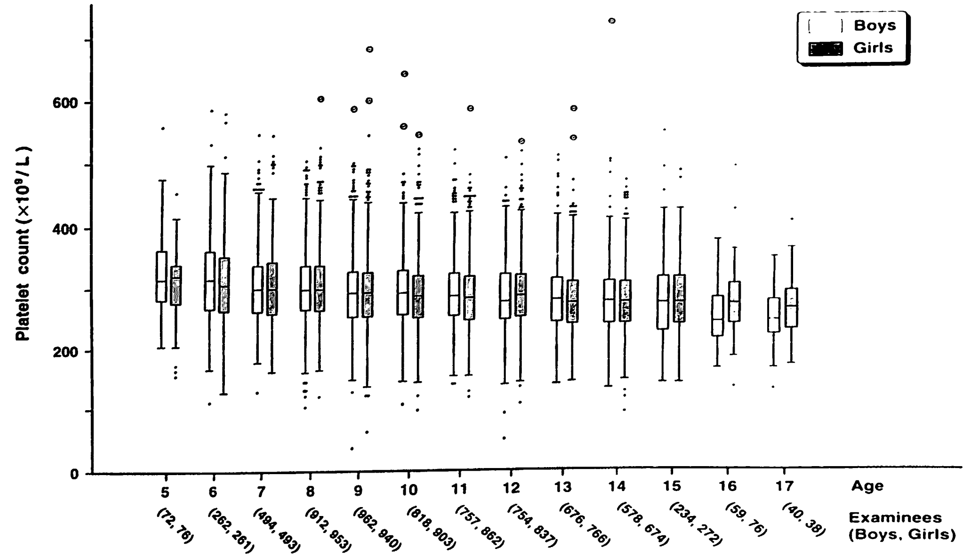

Figure 20. The box-and-whisker plots of platelet count by sex and age. See Figure 2 for details.

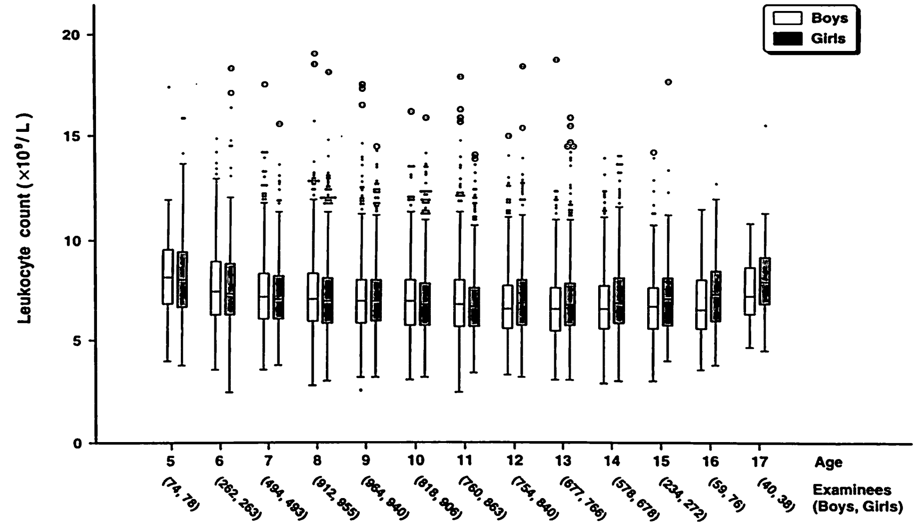

Figure 21. The box-and-whisker plots of leukocyte count by sex and age. See Figure 2 for details.

Figure 19 shows the relationship between MCV and age and sex. MCV level in girls in all age groups was higher than that in boys. An increase in MCV with age and a slight decrease in both girls and boys at the age of 16–17 was noted. The highest MCV level (102.9 fl) was registered in a girl with acute leukemia.

Figure 20 shows the relationship between platelet count and age and sex. The medians were within the normal range. The trend was toward an insignificant decrease in PLT with increasing age in both boys and girls. Thrombocytopenic purpura was found in 1 boy and 1 girl from Gomel City. A stable increase in PLT count was observed in a girl with congenital microspherocytic anemia after splenectomy. A decrease in PLT count level ($< 100 \times 10^9$/L) was found in 15 children.

The subsequent examination of 12 children revealed the following: 1 boy and 1 girl from Gomel City with idiopathic thrombocytopenic purpura and 1 girl from Gomel with acute leukemia. In all remaining cases, the thrombocytopenia was a transitory and asymptomatic type and PLT count was within the normal range at the time of re-examination. Erroneous measurements were disclosed in 4 cases.

Figure 21 shows the distribution of WBC count by age and sex. The median of WBC count was within the normal range. WBC level decreased with age. Registered in 542 children, leukocytosis was associated with acute viral and bacterial infections and with exacerbations of chronic inflammatory diseases.

A decrease in WBC count was disclosed in 64 children during the initial examinations. A total of 39 children were re-examined. A stable decrease in WBC count was found in 4 boys: 2 boys from Gomelskii Rayon, 1 boy from Gomel City and 1 boy from Dobrushskii Rayon. These children are under careful observation. The remainder of cases with leukopenia were associated with viral infections, gastrointestinal tract ailments and the presence of chronic infectious foci in the body of the child.

Tables 5A and 5B show the frequency of hematological abnormalities in relation to

Table 5A. Frequency of boys with

Blood analysis		Place of									
Item (unit)[c]	Abnormality criteria	BRA	BKS	VET	GOR	DOB	ELS	ZIT	ZLO	KLN	KOR
Hb (g/L)	< 110	2			5				1		
		(0.7)			(0.2)				(0.5)		
	> 180										
WBC (×10⁹/L)	< 3.8	1		1	14	7					
		(0.3)		(4.0)	(0.6)	(1.4)					
	> 10.6	19	8	2	102	28	9		18	1	2
		(6.2)	(5.4)	(8.0)	(4.6)	(5.4)	(6.7)		(8.4)	(5.3)	(3.7)
PLT (×10⁹/L)	< 100								1		
									(0.5)		
	> 440	6	6		33	11	4		9	1	2
		(2.0)	(4.0)		(1.5)	(2.1)	(3.0)		(4.2)	(5.3)	(3.7)
MCV (fl)	< 80	35	16	15	376	48	7		18	3	3
		(11.5)	(10.7)	(60.0)	(16.8)	(9.3)	(5.2)		(8.4)	(15.8)	(5.6)
	> 100										
Number of chidren measured[d]		305	149	25	2237	516	134	1	214	19	54
Ly (×10⁹/L)	< 1.2	2			13	2	2		3		
		(6.7)			(0.7)	(0.7)	(1.8)		(1.5)		
	> 3.5	3	5	3	360	60	14		49	5	7
		(10.0)	(15.2)	(12.0)	(18.5)	(22.0)	(12.3)		(24.5)	(33.3)	(15.9)
Ne (×10⁹/L)	< 1.4	1	4	1	77	22	3		9		1
		(3.3)	(12.1)	(4.0)	(3.9)	(8.1)	(2.6)		(4.5)		(2.3)
	> 6.6		1	2	71	4	5		9	2	2
			(3.0)	(8.0)	(3.6)	(1.5)	(4.4)		(4.5)	(13.3)	(4.5)
Eo (×10⁹/L)	> 0.5	7	6	4	283	69	21		28	2	8
		(23.3)	(18.2)	(16.0)	(14.5)	(25.3)	(18.4)		(14.0)	(13.3)	(18.2)
Mo (×10⁹/L)	< 0.12	1	1		202	29	2		29		1
		(3.3)	(3.0)		(10.4)	(10.6)	(1.8)		(14.5)		(2.3)
	> 1.00	1	2	1	15	12	3		1	1	3
		(3.3)	(6.1)	(4.0)	(0.8)	(4.4)	(2.6)		(0.5)	(6.7)	(6.8)
Number of chidren measured[e]		30	33	25	1951	273	114	1	200	15	44

[a] Parenthetic entries refer to the percentage of the subjects while empty spaces denote the absence of subjects

[b] BRA, Braginskii; BKS, Buda-Koshelevskii; VET, Vetkovskii; GOR, Gomelskii; DOB, Dobrushskii; ELS, Loevskii; MOZ, Mozirskii; NAR, Narovlyanskii; OKT, Oktyabrskii; PET, Petrikovskii; REC, Rechitskii; City.

[c] Hb, hemoglobin; WBC, white blood cell (leukocyte); PLT, platelet; MCV, mean corpuscular volume; Ly,

[d] Number of children measured for Hb, WBC, PLT, MCV.

[e] Number of children measured for Ly, Ne, Eo, Mo.

hematological abnomalities by place of residence.[a]

residence[b]													Total
LEL	LOE	MOZ	NAR	OKT	PET	REC	ROG	SVT	HOY	CHE	GOC	MOC	
	3 (1.0)					12 (1.5)	2 (0.6)				7 (0.6)		32 (0.5)
	1 (0.3)					1 (0.1)							2 (0.0)
1 (4.8)	3 (1.0)				1 (1.4)	7 (0.9)			1 (0.6)		12 (1.0)		48 (0.7)
	15 (5.2)			1 (10.0)	7 (10.0)	27 (3.4)	5 (1.6)	1 (4.2)	4 (2.4)	1 (3.1)	47 (3.9)	4 (12.9)	301 (4.5)
											2 (0.2)		3 (0.0)
	3 (1.0)					9 (1.1)	2 (0.6)				20 (1.7)		106 (1.6)
4 (19.0)	29 (10.1)			5 (50.0)	10 (14.3)	158 (19.7)	52 (16.7)	6 (25.0)	11 (6.5)	6 (18.8)	343 (28.4)	11 (35.5)	1156 (17.4)
						1 (0.1)							1 (0.0)
21	286	3	2	10	70	803	311	24	169	32	1209	31	6625
1 (20.0)						3 (0.4)			4 (2.6)	1 (25.0)	13 (1.4)		44 (0.9)
	6 (8.8)				2 (15.4)	117 (14.8)	72 (23.4)	5 (23.8)	14 (9.0)		132 (13.7)	2 (9.1)	856 (17.0)
	3 (4.4)					37 (4.7)	27 (8.8)		2 (1.3)		70 (7.3)		257 (5.1)
	3 (4.4)					21 (2.7)	5 (1.6)		5 (3.2)	1 (25.0)	28 (2.9)	2 (9.1)	161 (3.2)
2 (40.0)	9 (13.2)	2 (66.7)		3 (37.5)	1 (7.7)	96 (12.1)	24 (7.8)	1 (4.8)	28 (17.9)	1 (25.0)	95 (9.9)	2 (9.1)	692 (13.7)
	9 (13.2)			1 (12.5)		143 (18.1)	24 (7.8)	3 (14.3)	12 (7.7)		57 (5.9)	3 (13.6)	517 (10.2)
	1 (1.5)					8 (1.0)	5 (1.6)		2 (1.3)	1 (25.0)	21 (2.2)		77 (1.5)
5	68	3		8	13	791	308	21	156	4	961	22	5046

with abnormalities.

Elskii; ZIT, Zitkovichskii; ZLO, Zlobinskii; KLN, Kalinkovichskii; KOR, Kormyanskii; LEL, Lelchitskii; LOE, ROG, Rogachevskii; SVT, Svetlogorskii; HOY, Hoynikskii; CHE, Checherskii; GOC, Gomel City; MOC, Mozir

lymphocyte; Ne, neutrophil; Eo, eosinophil; Mo, monocyte.

Table 5B. Frequency of girls with

Blood analysis		Place of									
Item (unit)[c]	Abnormality criteria	BRA	BKS	VET	GOR	DOB	ELS	ZIT	ZLO	KLN	KOR
Hb (g/L)	< 110				5 (0.2)	4 (0.7)			1 (0.4)		
	> 160				8 (0.3)	2 (0.3)					
WBC (×10⁹/L)	< 3.6	1 (0.4)			6 (0.3)	1 (0.2)					
	> 11.0	14 (5.0)	18 (9.4)		71 (3.1)	19 (3.2)	5 (2.7)		15 (5.4)	2 (9.1)	2 (3.5)
PLT (×10⁹/L)	< 100								1 (0.4)		
	> 440	5 (1.8)	4 (2.1)	1 (3.7)	26 (1.1)	5 (0.8)	3 (1.6)		9 (3.2)		2 (3.5)
MCV (fl)	< 80	20 (7.1)	16 (8.3)	11 (40.7)	207 (8.9)	23 (3.9)	7 (3.8)		12 (4.3)	3 (13.6)	7 (12.3)
	> 100	1 (0.4)									
Number of chidren measured[d]		282	192	27	2320	596	183	2	280	22	57
Ly (×10⁹/L)	< 1.2			1 (4.3)	18 (0.9)	1 (0.3)	4 (2.8)		1 (0.4)		
	> 3.5	3 (8.6)	2 (4.1)	1 (4.3)	405 (20.5)	56 (18.1)	11 (7.7)		76 (28.0)	4 (21.1)	8 (16.3)
Ne (×10⁹/L)	< 1.4	6 (17.1)	1 (2.0)	1 (4.3)	80 (4.1)	13 (4.2)	10 (7.0)	1 (50.0)	11 (4.1)	2 (10.5)	2 (4.1)
	> 6.6		1 (2.0)		74 (3.7)	10 (3.2)	7 (4.9)		10 (3.7)	1 (5.3)	
Eo (×10⁹/L)	> 0.5	5 (14.3)	8 (16.3)	3 (13.0)	284 (14.4)	67 (21.6)	32 (22.4)		47 (17.3)	2 (10.5)	8 (16.3)
Mo (×10⁹/L)	< 0.12	5 (14.3)	1 (2.0)	1 (4.3)	223 (11.3)	33 (10.6)	5 (3.5)		40 (14.8)	3 (15.8)	7 (14.3)
	> 1.00	1 (2.9)			13 (0.7)	6 (1.9)	3 (2.1)		2 (0.7)		
Number of chidren measured[e]		35	49	23	1975	310	143	2	271	19	49

[a] Parenthetic entries refer to the percentage of the subjects while empty spaces denote the absence of subjects

[b] BRA, Braginskii; BKS, Buda-Koshelevskii; VET, Vetkovskii; GOR, Gomelskii; DOB, Dobrushskii; ELS, Loevskii; MOZ, Mozirskii; NAR, Narovlyanskii; OKT, Oktyabrskii; PET, Petrikovskii; REC, Rechitskii; City.

[c] Hb, hemoglobin; WBC, white blood cell (leukocyte); PLT, platelet; MCV, mean corpuscular volume; Ly,

[d] Number of children measured for Hb, WBC, PLT, MCV.

[e] Number of children measured for Ly, Ne, Eo, Mo.

hematological abnomalities by place of residence.[a]

residence[b]													Total
LEL	LOE	MOZ	NAR	OKT	PET	REC	ROG	SVT	HOY	CHE	GOC	MOC	
				1	1	14	7	1			7		41
				(5.6)	(1.0)	(1.7)	(1.9)	(3.3)			(0.5)		(0.6)
						3	3				5		21
						(0.4)	(0.8)				(0.4)		(0.3)
						3	1				4		16
						(0.4)	(0.3)				(0.3)		(0.2)
1	6	1			6	19	7	2	4	1	42	1	236
(1.9)	(2.3)	(10.0)			(5.9)	(2.3)	(1.9)	(6.7)	(2.6)	(2.6)	(3.2)	(2.7)	(3.3)
						1							2
						(0.1)							(0.0)
	3				1	10	5	1	4	2	14	1	96
	(1.1)				(1.0)	(1.2)	(1.4)	(3.3)	(2.6)	(5.3)	(1.1)	(2.7)	(1.3)
8	21	1		3	13	76	39	4	4	1	219	5	700
(15.4)	(8.0)	(10.0)		(16.7)	(12.7)	(9.3)	(10.9)	(13.3)	(2.6)	(2.6)	(16.5)	(13.5)	(9.8)
						1							2
						(0.1)							(0.0)
52	261	10	1	18	102	817	359	30	152	38	1329	37	7167
	2					4	1		1		17		50
	(2.5)					(0.5)	(0.3)		(0.8)		(1.6)		(0.9)
6	11	1			3	117	76	3	4		163	3	953
(25.0)	(13.9)	(11.1)			(25.0)	(14.8)	(21.6)	(10.3)	(3.1)		(15.4)	(10.3)	(17.6)
	1			1	1	26	12	1	5		76	1	251
	(1.3)			(6.3)	(8.3)	(3.3)	(3.4)	(3.4)	(3.9)		(7.2)	(3.4)	(4.6)
1	4			1	1	16	7	4	4		36	2	179
(4.2)	(5.1)			(6.3)	(8.3)	(2.0)	(2.0)	(13.8)	(3.1)		(3.4)	(6.9)	(3.3)
4	13	3				70	28	2	15	1	110	2	704
(16.7)	(16.5)	(33.3)				(8.8)	(8.0)	(6.9)	(11.8)	(20.0)	(10.4)	(6.9)	(13.0)
	11	1		2		153	36	1	7		67	2	598
	(13.9)	(11.1)		(12.5)		(19.3)	(10.2)	(3.4)	(5.5)		(6.3)	(6.9)	(11.1)
	2			2		9	3	1	2	1	20		65
	(2.5)			(12.5)		(1.1)	(0.9)	(3.4)	(1.6)	(20.0)	(1.9)		(1.2)
24	79	9		16	12	793	352	29	127	5	1056	29	5407

with abnormalities.

Elskii; ZIT, Zitkovichskii; ZLO, Zlobinskii; KLN, Kalinkovichskii; KOR, Kormyanskii; LEL, Lelchitskii; LOE, ROG, Rogachevskii; SVT, Svetlogorskii; HOY, Hoynikskii; CHE, Checherskii; GOC, Gomel City; MOC, Mozir

lymphocyte; Ne, neutrophil; Eo, eosinophil; Mo, monocyte.

Table 6A. Frequency of boys with hematological abnormalities by ^{137}Cs level.[a]

Blood analysis		Whole body ^{137}Cs count per body weight (Bq/kg)					Total
Item (unit)[b]	Abnormality criteria	0–50	50–100	100–200	200–500	500–	
Hb (g/L)	< 110	24 (0.5)	5 (0.4)	3 (0.5)			32 (0.5)
	> 180	2 (0.0)					2 (0.0)
WBC (×10⁹/L)	< 3.8	37 (0.8)	8 (0.6)	2 (0.4)		1 (5.9)	48 (0.7)
	> 10.6	199 (4.3)	70 (5.5)	24 (4.3)	8 (5.3)		301 (4.5)
PLT (×10⁹/L)	< 100	3 (0.1)					3 (0.0)
	> 440	75 (1.6)	16 (1.3)	13 (2.4)	1 (0.7)	1 (5.9)	106 (1.6)
MCV (fl)	< 80	867 (18.7)	183 (14.5)	80 (14.5)	21 (13.8)	5 (29.4)	1156 (17.4)
	> 100		1 (0.1)				1 (0.0)
Number of chidren measured[c]		4638	1265	553	152	17	6625
Ly (×10⁹/L)	< 1.2	37 (1.0)	4 (0.4)	2 (0.6)	1 (1.5)		44 (0.9)
	> 3.5	599 (16.1)	178 (19.5)	61 (18.7)	16 (23.9)	2 (20.0)	856 (17.0)
Ne (×10⁹/L)	< 1.4	197 (5.3)	43 (4.7)	14 (4.3)	3 (4.5)		257 (5.1)
	> 6.6	116 (3.1)	38 (4.2)	5 (1.5)	2 (3.0)		161 (3.2)
Eo (×10⁹/L)	> 0.5	490 (13.1)	136 (14.9)	55 (16.8)	10 (14.9)	1 (10.0)	692 (13.7)
Mo (×10⁹/L)	< 0.12	369 (9.9)	109 (11.9)	32 (9.8)	5 (7.5)	2 (20.0)	517 (10.2)
	> 1.00	53 (1.4)	17 (1.9)	5 (1.5)	1 (1.5)	1 (10.0)	77 (1.5)
Number of chidren measured[d]		3727	915	327	67	10	5046

[a] Parenthetic entries refer to the percentage of the subjects while empty spaces denote the absence of subjects with abnormalities.

[b] Hb, hemoglobin; WBC, white blood cell (leukocyte); PLT, platelet; MCV, mean corpuscular volume; Ly, lymphocyte; Ne, neutrophil; Eo, eosinophil; Mo, monocyte.

[c] Number of children measured for Hb, WBC, PLT, MCV.

[d] Number of children measured for Ly, Ne, Eo, Mo.

place of residence and sex. Lymphocytosis was registered relatively frequently in girls from Zlobinskii (30%) and Rogachevskii (22.2%) Rayons and in boys from Rogachevskii Rayon (24%). A decrease in MCV level (< 80 fl) was observed relatively frequently in boys (27.1%) and girls (16%) from Gomel City. The highest eosinophil count was noted in boys (25.9%) and in girls (21.3%) from Dobruhskii Rayon and in girls (22.7%) from Elskii Rayon. A total of 1,396 children showed an increase in eosinophil count in the blood ($> 0.5 \times 10^9$/L). Of these, 650 were re-examined, and eosinophilia was confirmed in 263 children. Responses to the questionnaire suggested that the etiology was mainly related to helminthic invasions and allergic disorders.

It is difficult to draw a definite conclusion about the relationship between ^{137}Cs accumulation level in the body and the frequency of hematological abnormalities because the number of children with ^{137}Cs specific activity exceeding 200 Bq/kg was small (Tables 6A and 6B).

A statistically significant correlation was observed between PLT and eosinophil count, but the correlation coefficient was not large: 95% confidence interval was $0.13 < \rho < 0.17$.

We determined the ferritin level in the blood serum of children from three groups

Table 6B. Frequency of girls with hematological abnormalities by ^{137}Cs level.[a]

Blood analysis		Whole body ^{137}Cs count per body weight (Bq/kg)					Total
Item (unit)[b]	Abnormality criteria	0–50	50–100	100–200	200–500	500–	
Hb (g/L)	< 110	29 (0.6)	9 (0.7)	2 (0.4)		1 (9.1)	41 (0.6)
	> 160	19 (0.4)	1 (0.1)	1 (0.2)			21 (0.3)
WBC (×10^9/L)	< 3.6	13 (0.2)	3 (0.2)				16 (0.2)
	> 11.0	168 (3.2)	43 (3.3)	21 (4.2)	3 (3.3)	1 (9.1)	236 (3.3)
PLT (×10^9/L)	< 100	2 (0.0)					2 (0.0)
	> 440	63 (1.2)	21 (1.6)	12 (2.4)			96 (1.3)
MCV (fl)	< 80	536 (10.2)	103 (8.0)	53 (10.5)	6 (6.6)	2 (18.2)	700 (9.8)
	> 100	2 (0.0)					2 (0.0)
Number of chidren measured[c]		5267	1294	504	91	11	7167
Ly (×10^9/L)	< 1.2	38 (0.9)	9 (1.0)	2 (0.7)	1 (2.5)		50 (0.9)
	> 3.5	696 (16.6)	178 (20.3)	72 (24.8)	5 (12.5)	2 (18.2)	953 (17.6)
Ne (×10^9/L)	< 1.4	184 (4.4)	41 (4.7)	22 (7.6)	3 (7.5)	1 (9.1)	251 (4.6)
	> 6.6	149 (3.6)	19 (2.2)	8 (2.8)	2 (5.0)	1 (9.1)	179 (3.3)
Eo (×10^9/L)	> 0.5	514 (12.3)	123 (14.0)	60 (20.7)	4 (10.0)	3 (27.3)	704 (13.0)
Mo (×10^9/L)	< 0.12	455 (10.9)	97 (11.0)	42 (14.5)	4 (10.0)		598 (11.1)
	> 1.00	55 (1.3)	5 (0.6)	5 (1.7)			65 (1.2)
Number of chidren measured[d]		4188	878	290	40	11	5407

[a] Parenthetic entries refer to the percentage of the subjects while empty spaces denote the absence of subjects with abnormalities.

[b] Hb, hemoglobin; WBC, white blood cell (leukocyte); PLT, platelet; MCV, mean corpuscular volume; Ly, lymphocyte; Ne, neutrophil; Eo, eosinophil; Mo, monocyte.

[c] Number of children measured for Hb, WBC, PLT, MCV.

[d] Number of children measured for Ly, Ne, Eo, Mo.

in the course of the Chernobyl Sasakawa Project in 1994–1995. The first group consisted of 5 boys and 5 girls with normal Hb (> 110 g/L) and MCV (> 80 fl) levels from each of 10 age groups of 5–14 years (50 boys and 50 girls in all). Ferritin level increased with age but decreased in children aged 12–14 years. Girls showed a slightly lower ferritin level than boys at the age of 5–13 years. However, this parameter was approximately the same in both sexes at the age of 14 years old (Figure 22). The second group (95 children) consisted of children with MCV < 80 fl. The relationship between MCV and ferritin levels was plotted (Figure 23). A statistically significant correlation was observed between these parameters. The correlation coefficient was 0.3 ($p < 0.01$). The third group (49 children) consisted of children with Hb < 110 g/L. The correlation coefficient was 0.08 (Figure 24), which is not statistically significant.

We also studied the prevalence of eosinophilia in the spring and in the autumn. The frequency of eosinophilia was higher in the autumn than in the spring, a fact that may be attributable to an increase in parasitic disorders during the given period of time.

There was one case of leukemia (girl, born in 1984). The girl was in Gomel City at the time of the accident, and the city is still her place of residence. The ^{137}Cs specific activity in the body at the time of initial examination in December 1994 was 992 Bq

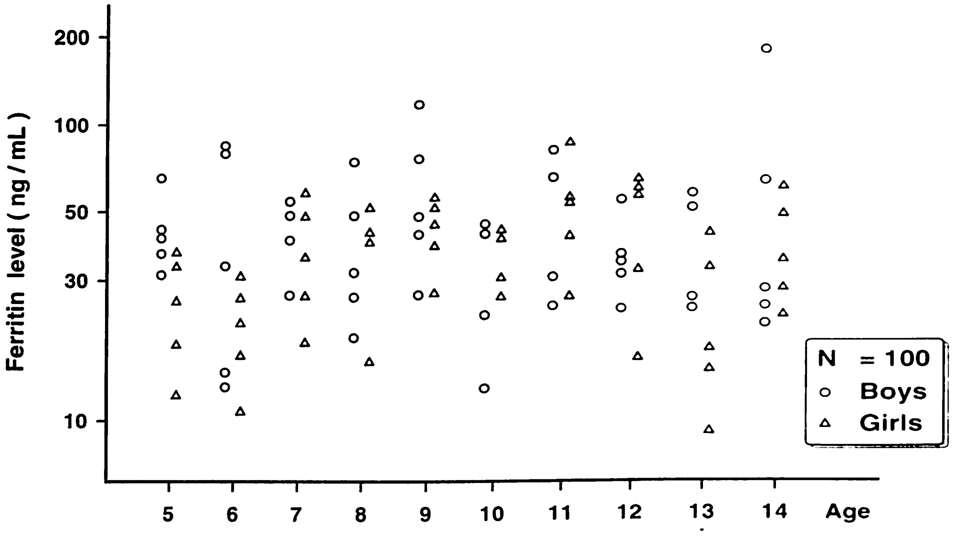

Figure 22. Distribution of ferritin level by age and sex in hematologically normal children.

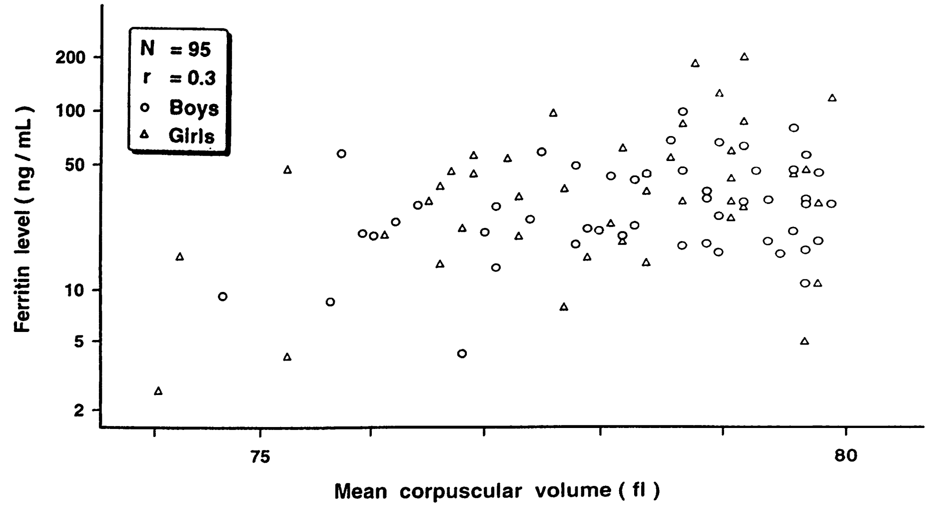

Figure 23. Scatter plots of mean corpuscular volume (MCV) and ferritin levels in children with MCV less than 80 fl.

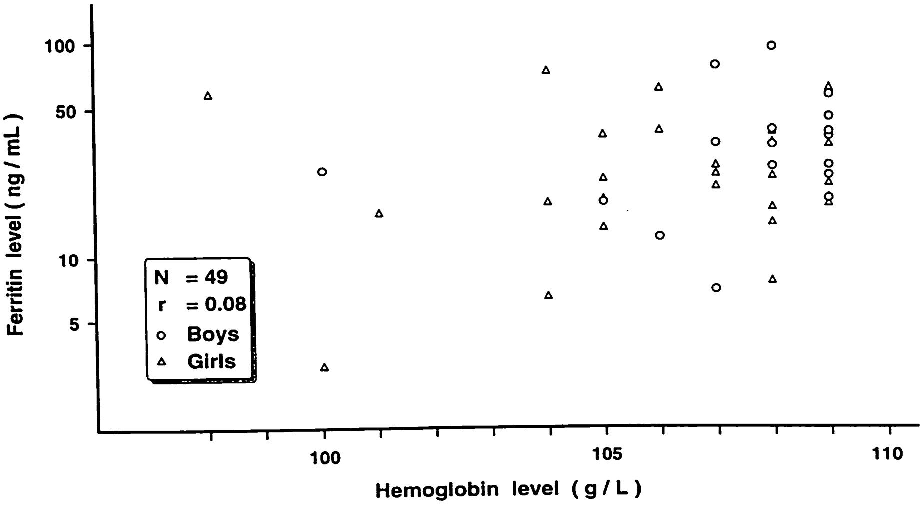

Figure 24. Scatter plots of hemoglobin (Hb) and ferritin levels in children with Hb less than 110 g/L.

(30 Bq/kg). The child was admitted to the Gomel Children's Hematology Department for a comprehensive examination and a course of treatment. The following final diagnosis was established: acute lymphoblast leukemia, pre-B-variant, Z1–Z2. She underwent a course of treatment according to the ALL-BF M-90 program with a remission on the 15th day. At the present time her state is satisfactory. The girl is on supporting therapy and is under the permanent observation of a hematologist.

4. Conclusions

It should be noted that the majority of children examined in the course of the Chernobyl Sasakawa Project over the past four years showed ^{137}Cs specific activity in the range from 30 to 80 Bq/kg. No significant difference in ^{137}Cs specific activity was found between boys and girls.

An increase in thyroid abnormalities, particularly childhood thyroid cancer, was noted in the examined children from the Gomel Oblast. A total of 23 children with thyroid cancer were found through the Chernobyl Sasakawa Project in the period from 1991 to 1994.

The analysis of screening results and repeated assays of peripheral blood revealed no relationship between hematological abnormalities and ^{137}Cs contamination level in the territory or ^{137}Cs internal exposure dose (Bq/kg).

Results of the Examination of the Health Status of Children in the Southern-Western Rayons of Bryansk Oblast

Klincy City Children's Hospital

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1. Introduction

As a result of the Chernobyl catastrophe, Russian territory was heavily exposed to radioactive isotopes released into the atmosphere. The fallout contained a very large number of fission products. Among the most radiologically significant were radioactive isotopes of iodine, cesium, strontium and transuranium elements. Six southwestern rayons (districts) of the Bryansk Oblast (Province), including the territory with a soil ^{137}Cs contamination level exceeding 15 Ci/km^2, were the most severely contaminated.

From the time of the fallout, the population residing in the contaminated areas has been exposed to external gamma radiation emitted mainly from ^{137}Cs, while ^{131}I was the major factor in the internal radiation in May 1986. The ^{131}I accumulated in the thyroid was the cause of exposure. At a later period, ^{137}Cs became a major factor in internal radiation, because residents in the exposed areas consumed food (milk, meat, mushrooms, forest berries and fish) contaminated by ^{137}Cs.

The long-term Sasakawa Chernobyl Project investigations of children residing in the southwestern rayons of Bryansk Oblast in the Russian Federation are carried out by the staff of the diagnostic laboratory at Klincy City Children's Hospital. During the period between May 1991 and December 1994, the children from five rayons in Bryansk Oblast with various ^{137}Cs contamination level were examined.

Figure 1 shows the rayons of the Bryansk Oblast with ^{137}Cs contamination level.

2. Materials and Methods

2.1 Study subjects

The subjects under study are children born in the period from 26 April 1976 to 26 April 1986 and residing in radionuclide-contaminated areas at the time of the examination.

The examinations were carried out by the same techniques and details of disease history collected by the same methods as those employed by the other centers. A mobile diagnostic laboratory equipped with suitable investigation facilities and donated by the Sasakawa Foundation was dispatched to the above-mentioned rayons of the Bryansk Oblast. Children were also brought to Klincy City to be examined using

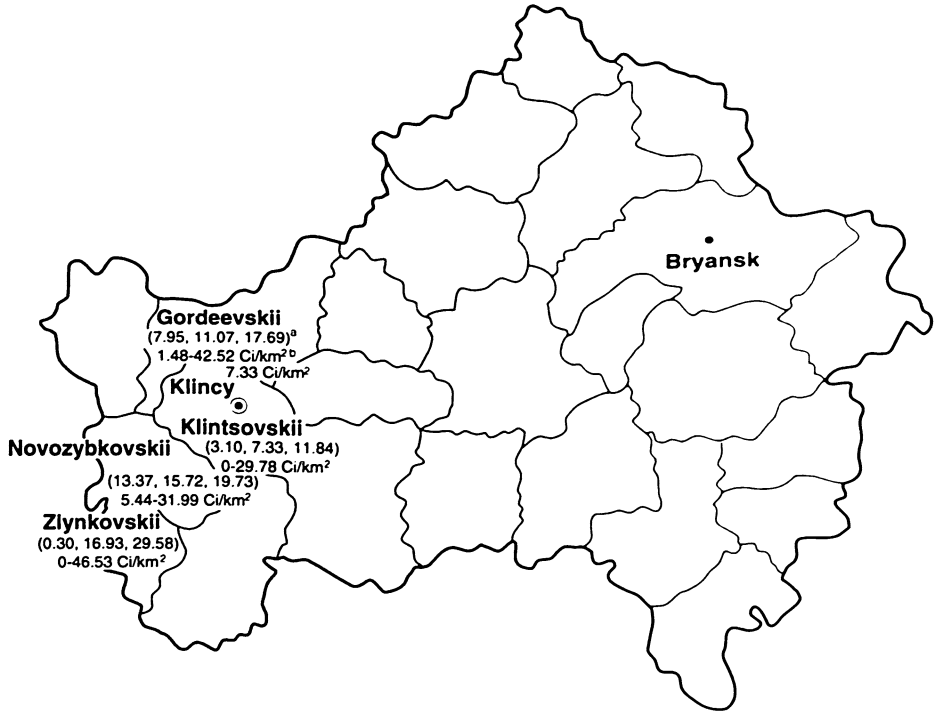

Figure 1. ^{137}Cs contamination levels (Ci/km^2) in the rayons of Bryansk Oblast.

[a] The triplets give the 25th, 50th and 75th sample percentiles of contamination levels.

[b] Minimum and maximum levels of contamination.

a set of stationary equipment. All diagnostic equipment was provided by the Sasakawa Memorial Health Foundation as a humanitarian aid donation. The Foundation also donated auxiliary facilities for storing biomaterials (serum and blood smears) obtained during examinations.

At the present time the center archive consists of about 16,000 samples.

2.2 Measurement of whole body ^{137}Cs concentration

^{137}Cs activity in the body of the children is measured with a WBC-101 gamma spectrometer manufactured by the Aloka Company. The following parameters are measured at the time of the examination: height; body weight and size of chest. ^{137}Cs specific activity is measured in Becquerel (Bq) and then calculated per kg body weight of the child.

2.3 Thyroid examinations

The complex examination of the thyroid includes an ultrasound investigation of the gland and determination of its functional state and of the presence or absence of the titers of anti-microsome antibodies (AMC) and anti-thyroglobulin antibodies (ATG). The ultrasound examination was performed by scanning the thyroid gland and automatically measuring its volume by outlining each image using an Aloka SSD-520 instrument. The criterion for goiter is a thyroid volume exceeding the volume calculated by the following formula:

$$LIMIT = 1.7 \times 10^{0.013 \times age + 0.0028 \times height} \times (body\ weight)^{0.15},$$

where *age* is the age of a child in years at the time of the examination; *height* is the height of a child in cm; and *body weight* is the weight of a child in kg. See Appendix B in *A Report on the 1993 Chernobyl Sasakawa Project Workshop*, 1993 for details.

In order to study thyroid function, serum free thyroxine (FT_4) and thyroid stimulating hormone (TSH) concentrations were determined by the immunometric technique using an Amerlite hormone analyzer system.

Ascertainment of the titers of AMC and ATG antibodies was based on the reaction of hemagglutination by microtitration.

Thyroid volume, its outlines, echogenity, the presence of thyroid abnormalities, nodules, cysts, calcificates, the levels of FT_4 and TSH and positive titers of AMC and ATG as well as cytological findings of thyroid aspiration obtained during fine needle aspiration biopsy were taken into consideration in the establishment of each diagnosis.

2.4 Hematological studies

Peripheral blood tests were conducted with Sysmex K-1000 and NE-7000 hemoanalyzers. Quantitative determinations of the white blood cell count (WBC), red blood cell count (RBC), hemoglobin concentration (Hb), platelet count (PLT), mean corpuscular volume (MCV), mean corpuscular hemoglobin concentration (MCHC) and mean corpuscular hemoglobin (MCH) were conducted. An analysis of the morphologic leukocyte differentiation was carried out with an Olympus microscope. Peripheral blood smears were stained by the May-Grünwald-Giemsa method.

3. Results

3.1 Study subjects

Table 1 shows the quantitative distribution of the children by sex and place of residence. The triplets give the 25th, 50th and 75th sample percentiles of age distribution at the time of examination in each group. A total of 17,467 children were examined from May 1991 to December 1994 (8,753 boys and 8,714 girls).

3.2 Measurement of whole body ^{137}Cs concentration

Figure 2 shows the relationship between ^{137}Cs specific activity and the age and sex among the children examined in 1994. The children with whole body ^{137}Cs count less than the detection limit, i.e. 540 Bq, were excluded from the figure. The number of boys and girls excluded in each age group was as follows (girls in parentheses): 7-year, 1(2); 8-year, 19(24); 9-year, 19(11); 10-year, 8(8); 11-year, 9(7); 12-year, 7(14); 13-year, 10(12); 14-year, 15(10); 15-year, 5(9); 16-year, 3(3); and 17-year, 1(2). The median of ^{137}Cs specific activity was independent of sex in all age groups and was in the range of 50–100 Bq/kg.

Figure 3 shows the relationship between ^{137}Cs specific activity and place of resi-

Table 1. Classification of study subjects by sex and place of residence.[a]

Plece of residence	Boys	Girls	Total
Klintsovskii	1189 (9, 11, 13)	1199 (9, 11, 13)	2388 (9, 11, 13)
Klincy City	4851 (9, 11, 13)	4734 (9, 11, 13)	9585 (9, 11, 13)
Novozybkovskii	1340 (9, 11, 13)	1332 (9, 11, 13)	2672 (9, 11, 13)
Zlynkovskii	774 (10, 12, 14)	832 (10, 12, 14)	1606 (10, 12, 14)
Gordeevskii	599 (10, 12, 14)	617 (10, 12, 14)	1216 (10, 12, 14)
Total	8753 (9, 11, 13)	8714 (9, 11, 13)	17 467 (9, 11, 13)

[a] Each triplet gives the 25th, 50th and 75th sample percentiles of age distribution at the time of examination.

dence. The relationship is based on the results of measurements taken in children examined from 15 May 1991 to 31 December 1994. The number of children excluded from the figure having whole body ^{137}Cs count less than 540 Bq was as follows: 105 in Klincy City; 15 in Novozybkovskii; 27 in Zlynkovskii; and 21 in Gordeevskii Rayons.

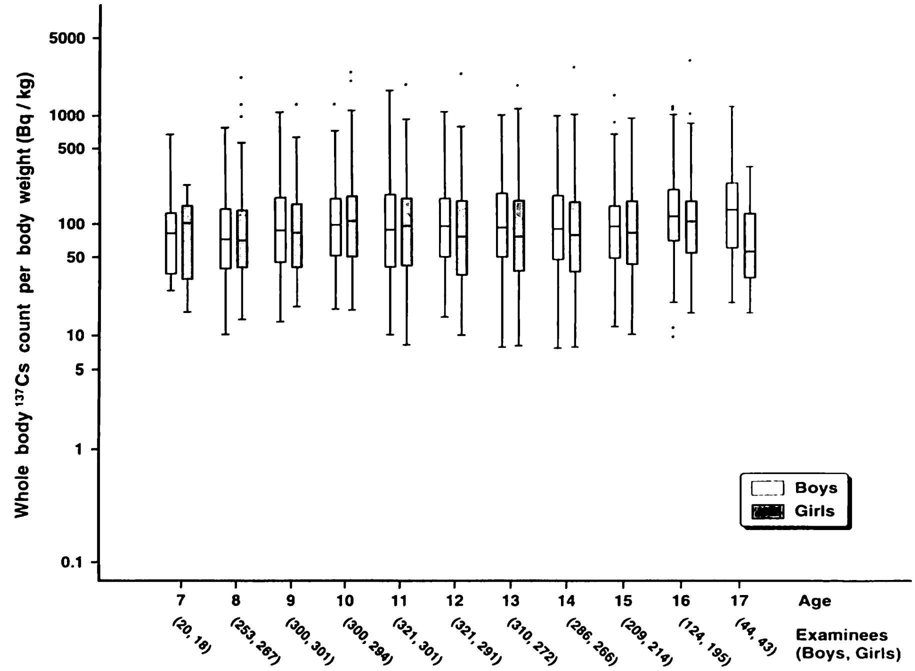

Figure 2. The box-and-whisker plots of whole body ^{137}Cs count per kg body weight by sex and age among children examined in 1994. The children with whole body ^{137}Cs count less than the detection limit (540 Bq) were excluded. The bottom and top ends of the box and the bar inside the box correspond to the 25th, 75th and 50th sample percentiles, respectively. The black dot and the double circle with black dot represent extreme values, called "outside" and "far out," respectively.

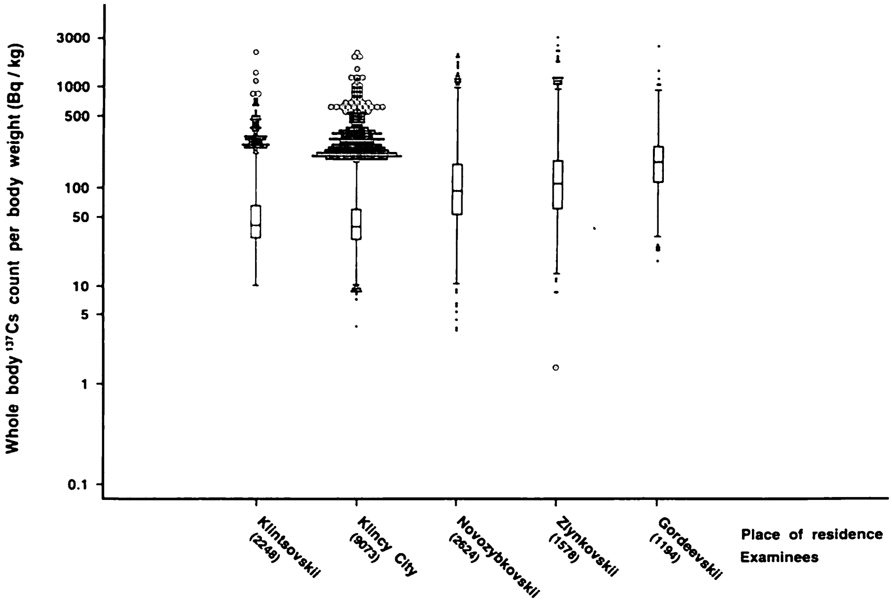

Figure 3. The box-and-whisker plots of whole body ^{137}Cs count per kg body weight by place of residence among children examined from 1991 to 1994. The children with whole body ^{137}Cs count less than the detection limit (540 Bq) were excluded. See Figure 2 for details.

As shown in the plot, the majority of ^{137}Cs specific activity levels in children from Gordeevskii Rayon was in the range of 100–200 Bq/kg. Children from Zlynkovskii and Novozybkovskii Rayons showed ^{137}Cs specific activity levels in the range of 100–150 Bq/kg, whereas children from Klincy City showed 10–50 Bq/kg.

3.3 Thyroid examinations

Figure 4 shows the thyroid volume change in relation to sex and age. The thyroid volume increased with the age of children.

Figure 5 shows the prevalence of goiter by sex and place of residence. The highest prevalence of goiter was observed in children from Gordeevskii Rayon (45.7% in boys and 60.0% in girls) and in children from Klincy City (40.5% in boys and 41.7% in girls). The prevalence of goiter was higher in girls than in boys in all rayons except Novozybkovskii Rayon.

Figure 6 shows the prevalence of goiter by ^{137}Cs contamination level in the place of residence at the time of the examination. No relationship was observed between the prevalence of goiter and ^{137}Cs contamination level in the place of residence. Figure 7 shows the prevalence of goiter by ^{137}Cs contamination level in the place of residence at the time of the accident. The highest prevalence of goiter was registered in children residing in the areas with a ^{137}Cs contamination level in the range of 15–20 Ci/km^2 (54.5% in boys and 57.4% in girls). The accuracy of the data on the prevalence of goiter by ^{137}Cs contamination level ranging higher than 40 Ci/km^2 is not statistically reliable because the number of children residing in these areas was very small.

Figure 8 shows the prevalence of goiter in boys and girls by whole body ^{137}Cs

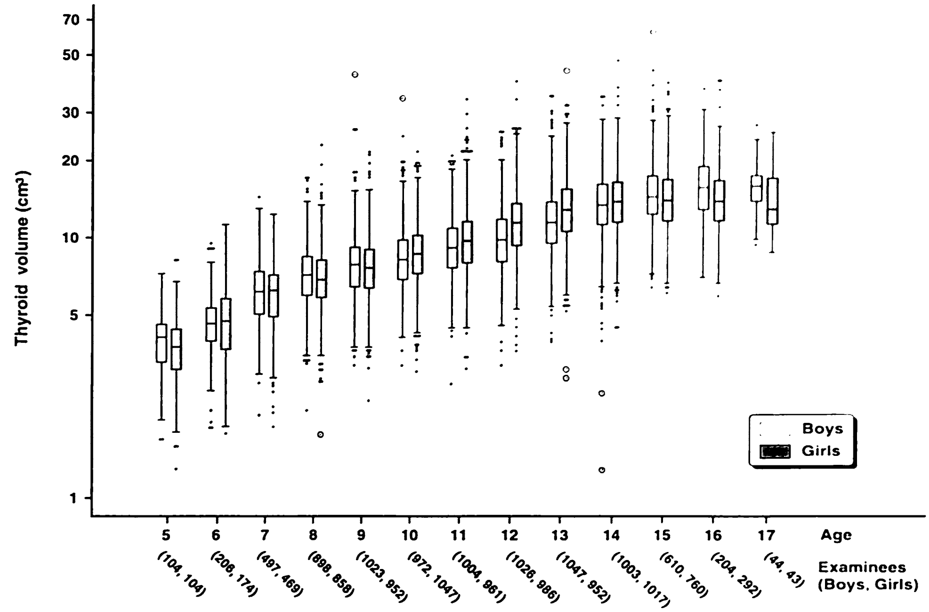

Figure 4. The box-and-whisker plots of thyroid volume by sex and age. See Figure 2 for details.

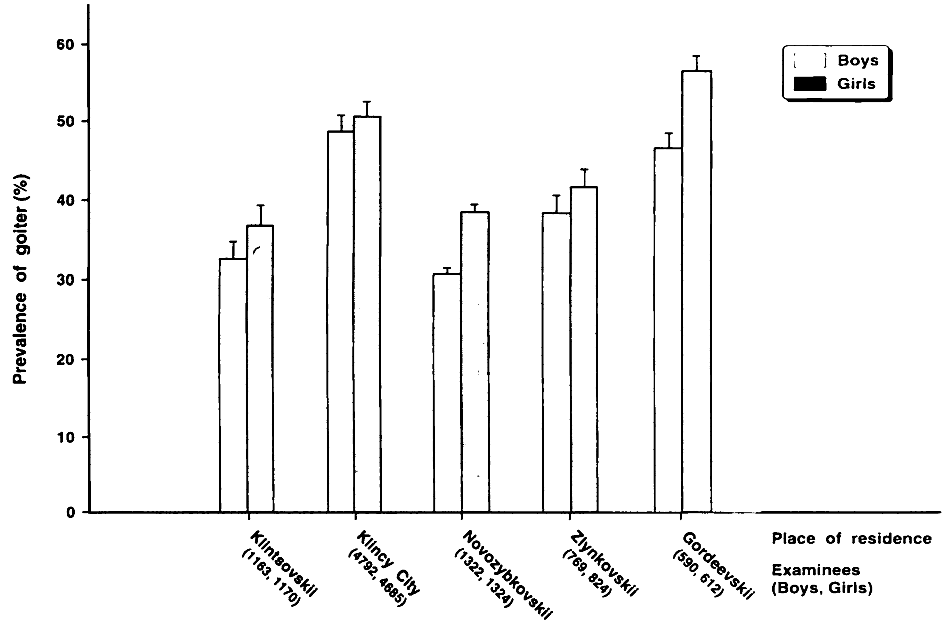

Figure 5. Prevalence of goiter by sex and place of current residence. The whiskers denote the standard errors. See page 56 for the definition of goiter.

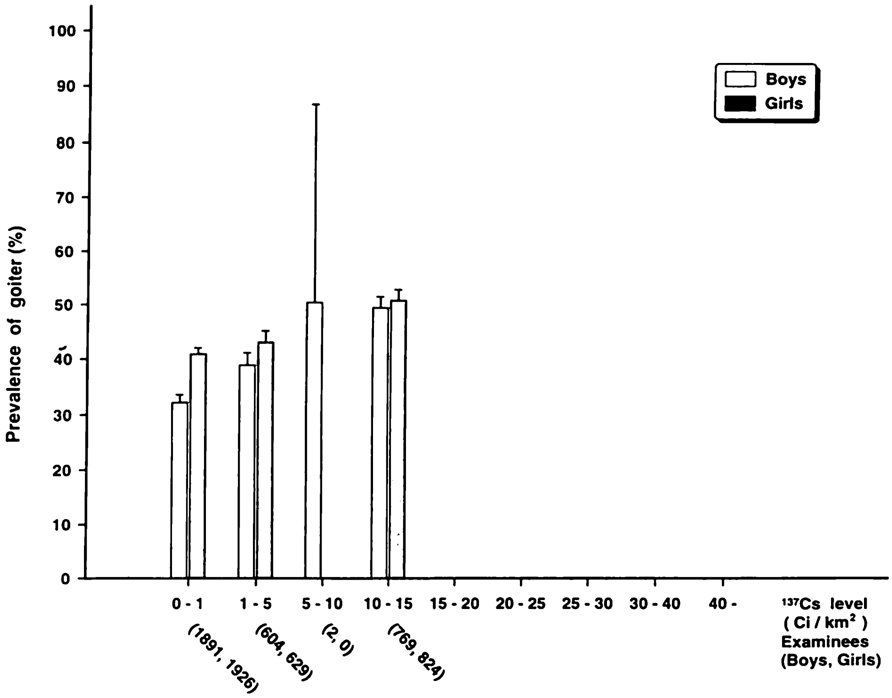

Figure 6. Prevalence of goiter by sex and contamination level (Ci/km^2) in the place of current residence. The whiskers denote the standard errors. See page 56 for the definition of goiter.

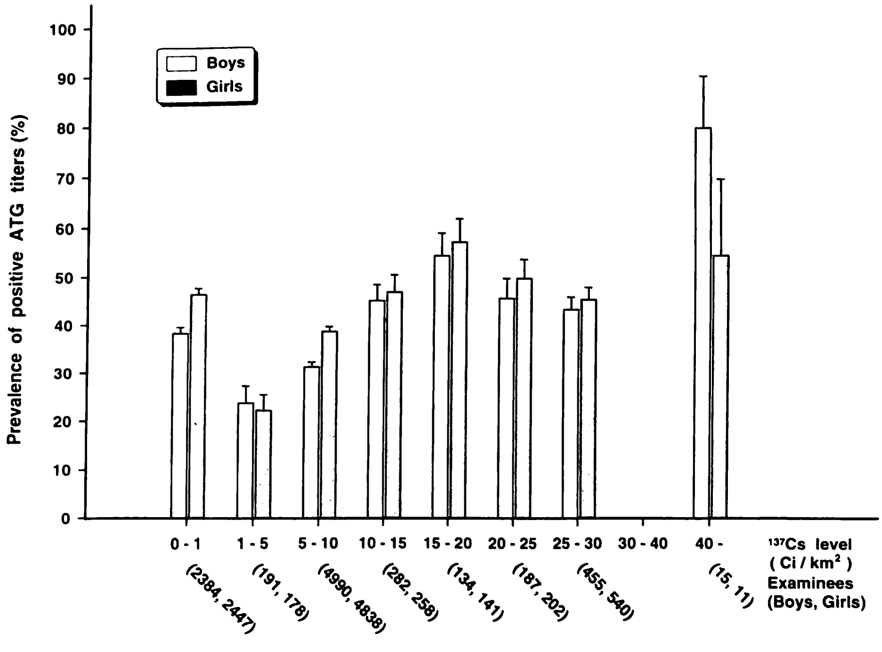

Figure 7. Prevalence of goiter by sex and contamination level (Ci/km^2) in the place of residence at the time of the accident. The whiskers denote the standard errors. See page 56 for the definition of goiter.

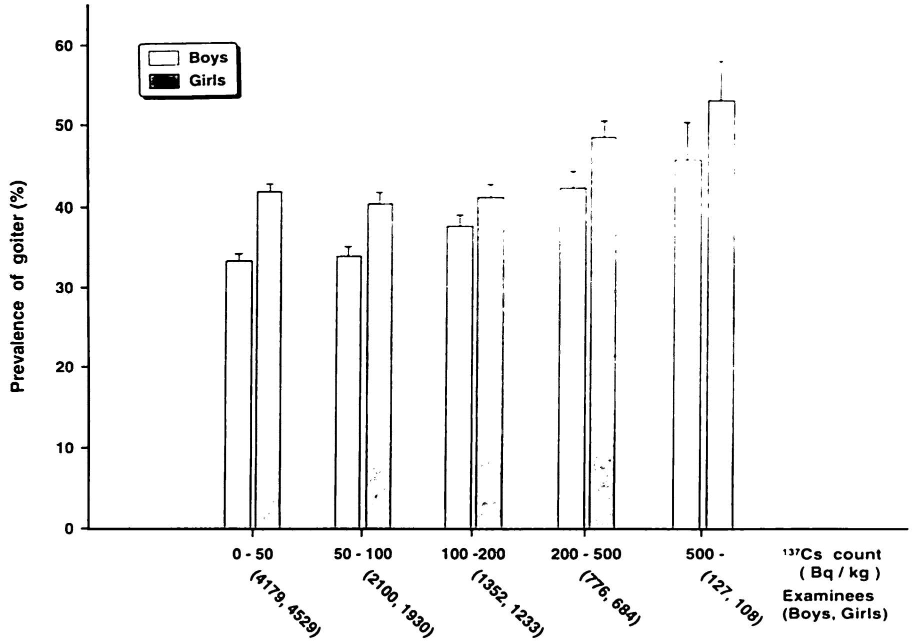

Figure 8. Prevalence of goiter by sex and whole body ^{137}Cs count per kg body weight. The whiskers denote the standard errors. See page 56 for the definition of goiter.

specific activity. The prevalence of goiter in boys increased with the increase in ^{137}Cs specific activity from 33.4% (in the range of 0–50 Bq/kg) to 45.7% (in the range higher than 500 Bq/kg). The prevalence of goiter in girls with ^{137}Cs specific activity ranging from 0 to 50 Bq/kg was 42.3%. The prevalence of goiter with ^{137}Cs specific activity in the range of 50–100 and 100–200 Bq/kg was 40.5% and 41.4%, respectively. There was a trend toward a higher prevalence of goiter among girls in the range of 200–500 Bq/kg and higher. It ranged from 48.5% to 52.8%.

Table 2 shows the classification of thyroid abnormalities by sex and place of residence. The most common abnormalities found during thyroid examinations were nodules, cysts, changes in echogenity and anomalies. Changes in echogenity account for the largest proportion of deviations from the normal range in ultrasound examinations; a local or diffuse decrease or increase was determined in 1.8% of boys and in 2.5% of girls. These deviations were found relatively frequently in girls (3.4%) and boys (2.4%) residing in Klincy City.

Nodular lesions were found relatively frequently in girls from Novozybkovskii (0.9%) and in boys from Zlynkovskii (0.8%) Rayons. Four cases of thyroid cancer were found in the period from 1993 to 1994. All the cancer cases were confirmed cytologically: 3 cases in the Klintsovskii Center and 1 case in MRRC, Obninsk City. A girl from Novozybkovskii Rayon born in 1986 has medullar carcinoma while 3 children from Klincy City (a boy and girl born in 1984 and a boy born in 1981) have follicular-papillary carcinoma.

Table 3 shows the number of children with positive titers of ATG and AMC

Table 2. Subjects with thyroid abnormalities by sex and place of residence.

Place of residence	Number of subjects examined		Diagnosis									
			Nodular lesion		Cystic lesion		Abnormal echogenity		Anomaly		Cancer	
	B[a]	G[a]	B	G	B	G	B	G	B	G	B	G
Klintsovskii	1163	1170	3	2	0	0	5	8	0	0	0	0
Klincy City	4792	4685	26	24	6	8	117	162	7	6	2	1
Novozybkovskii	1322	1324	9	12	6	12	11	24	1	1	0	1
Zlynkovskii	769	824	6	4	7	5	12	12	2	0	0	0
Gordeevskii	590	612	0	3	3	4	11	14	0	0	0	0
Total	8636	8615	44	45	22	29	156	220	10	7	2	2

[a] B, boys, G, girls.

Table 3. Prevalence of positive ATG (anti-thyroglobulin antibody) and AMC (anti-microsome antibody) titers by sex and place of residence.[a]

Place of residence	Number of subjects measured			Antibody					
				Anti-thyroglobulin			Anti-microsome		
	Total	Boys	Girls	Total	Boys	Girls	Total	Boys	Girls
Klintsovskii	2366	1174	1192	29 (1.2)	10 (0.9)	19 (1.6)	45 (1.9)	10 (0.9)	35 (2.9)
Klincy City	9287	4701	4586	105 (1.1)	27 (0.6)	78 (1.7)	188 (2.0)	50 (1.1)	138 (3.0)
Novozybkovskii	2647	1329	1318	38 (1.4)	10 (0.8)	28 (2.1)	34 (1.3)	8 (0.6)	26 (2.0)
Zlynkovskii	1587	767	820	26 (1.6)	8 (1.0)	18 (2.2)	21 (1.3)	4 (0.5)	17 (2.1)
Gordeevskii	1211	598	613	15 (1.2)	4 (0.7)	11 (1.8)	15 (1.2)	4 (0.7)	11 (1.8)
Total	17 098	8569	8529	213 (1.2)	59 (0.7)	154 (1.8)	303 (1.8)	76 (0.9)	227 (2.7)

[a] Number of subjects with percentages in parentheses.

antibodies by sex and place of residence. The total number of investigations was 17,098. The prevalence of positive ATG titers ranged from 1.1% among children from Klincy City to 1.6% among children from Zlynkovskii Rayon. The prevalence of positive titers of ATG antibodies was 2.6 times higher in girls than in boys. Positive titers of AMC antibodies in girls were 3 times as frequent as those in boys, and the prevalence of AMC titers was noted in the range from 1.2% in Gordeevskii Rayon to 2.0% in Klincy City.

Figure 9 shows the relationship between the prevalence of positive titers of ATG antibodies in boys and girls and ^{137}Cs specific activity. No relationship between these two values could be established. The prevalence of ATG titers in girls was higher than in boys irrespective of the contamination level in the place of residence at the time of the accident (Figure 10). As shown in Figure 11, the prevalence of positive titers of

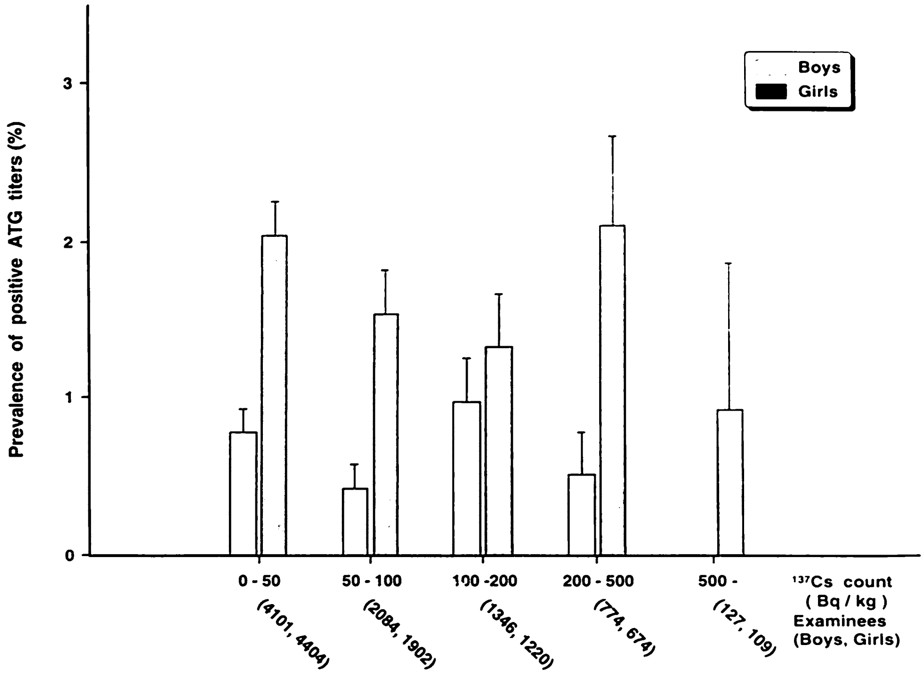

Figure 9. Prevalence of positive ATG titers by sex and whole body ^{137}Cs count per kg body weight. The whiskers denote the standard errors.

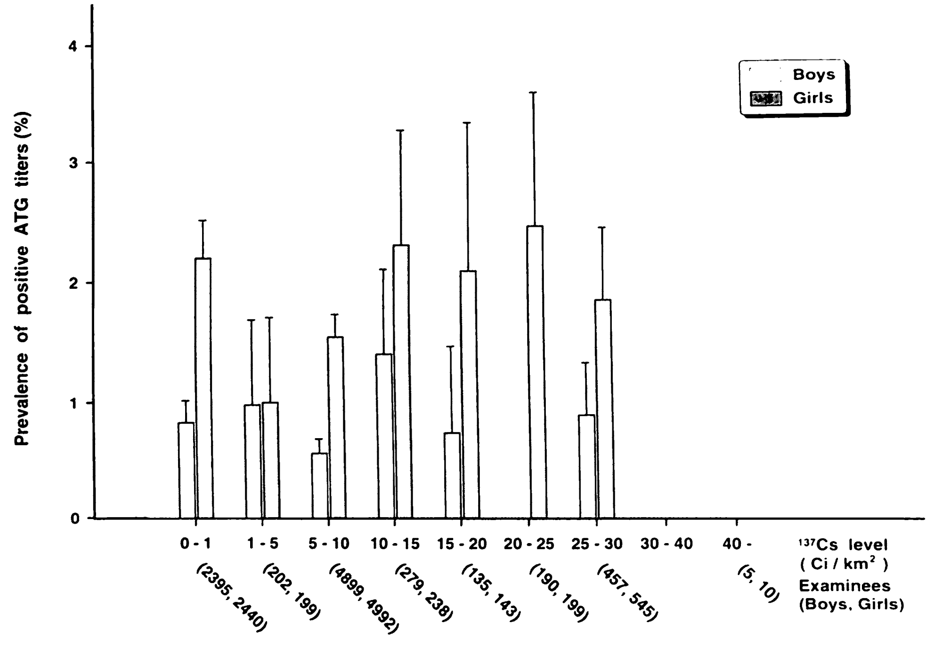

Figure 10. Prevalence of positive ATG titers by sex and contamination level (Ci/km^2) in the place of residence at the time of the accident. The whiskers denote the standard errors.

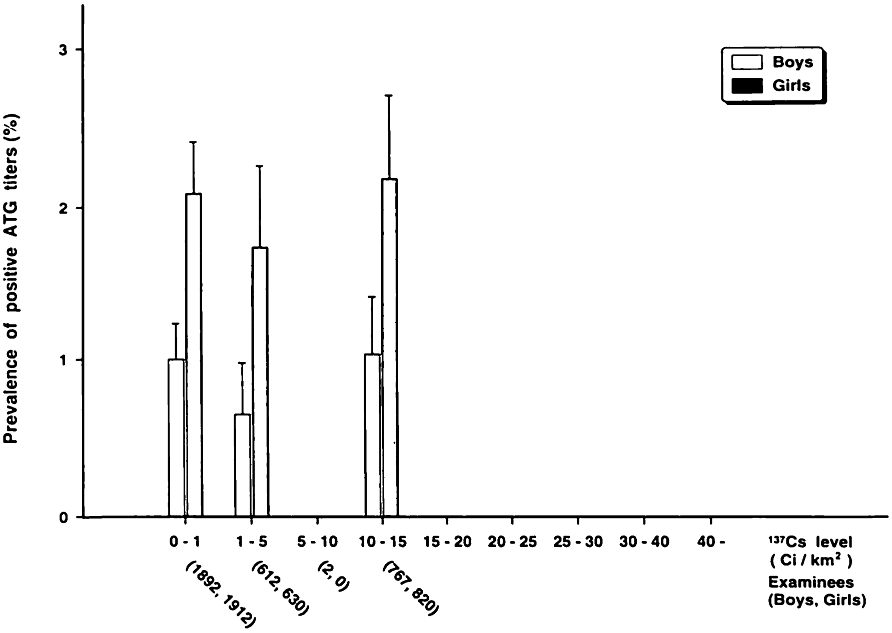

Figure 11. Prevalence of positive ATG titers by sex and contamination level (Ci/km^2) in the place of current residence. The whiskers denote the standard errors.

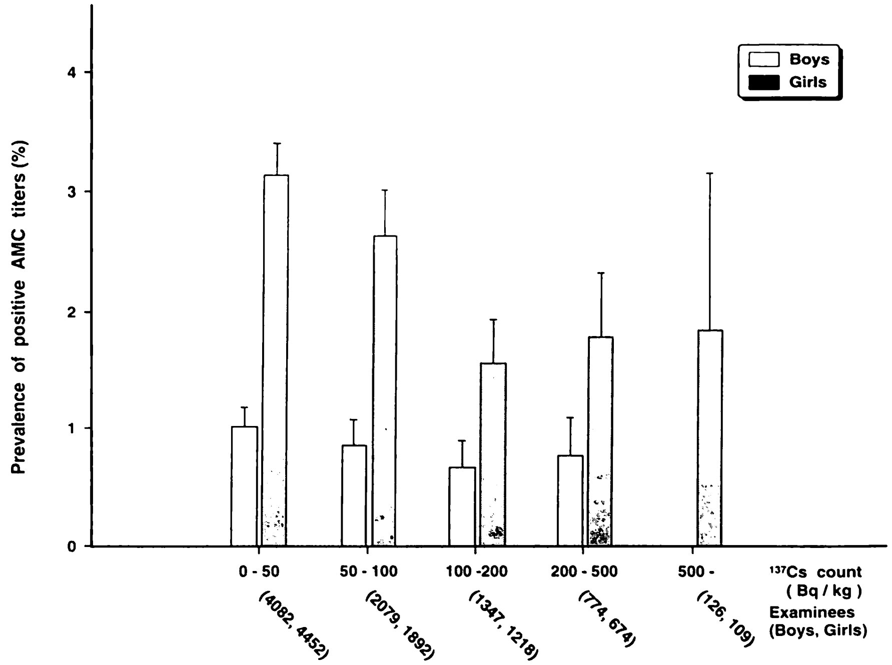

Figure 12. Prevalence of positive AMC titers by sex and whole body ^{137}Cs count per kg body weight. The whiskers denote the standard errors.

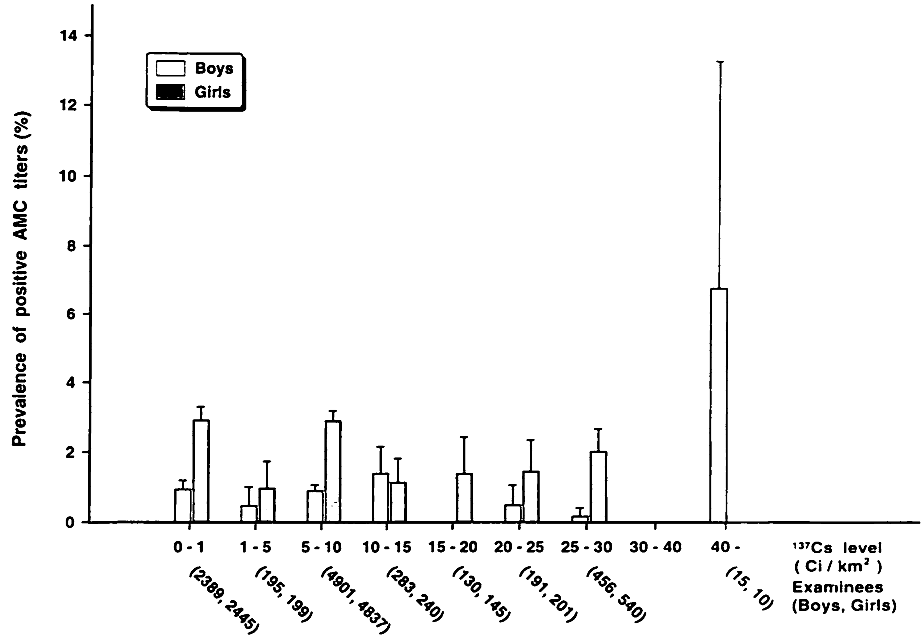

Figure 13. Prevalence of positive AMC titers by sex and contamination level (Ci/km^2) in the place of residence at the time of the accident. The whiskers denote the standard errors.

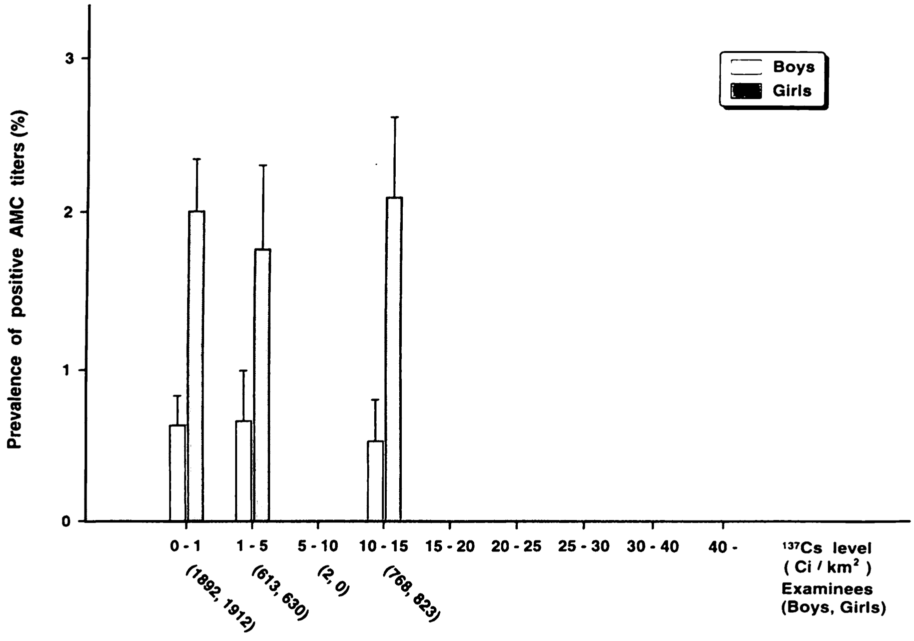

Figure 14. Prevalence of positive AMC titers by sex and contamination level (Ci/km^2) in the place of current residence. The whiskers denote the standard errors.

Table 4. Number of subjects with hypothyroidism and hyperthyroidism by sex and place of residence.

Place of residence	Number of subjects with measurement			Hypothyroidism[a]			Hyperthyroidism[b]		
	Total	Boys	Girls	Total	Boys	Girls	Total	Boys	Girls
Klintsovskii	2349	1166	1183	0	0	0	0	0	0
Klincy City	9167	4647	4520	10	5	5	5	1	4
Novozybkovskii	2620	1315	1305	2	0	2	2	0	2
Zlynkovskii	1579	765	814	2	0	2	0	0	0
Gordeevskii	1203	597	606	1	1	0	2	1	1
Total	16 918	8490	8428	15	6	9	9	2	7

[a] Diagnosed when free $T_4 < 10.0$ pmol/L and TSH > 2.90 μIU/mL.
[b] Diagnosed when free $T_4 > 25.0$ pmol/L and TSH < 0.24 μIU/mL.

ATG antibodies did not correlate with the contamination level in the place of residence of the children examined.

Figure 12 shows the relationship between the prevalence of positive AMC titers and ^{137}Cs specific activity in boys and girls. No relationship was found between these two values. Figure 13 shows the relationship between the prevalence of positive titers of AMC antibodies and the level of contamination in the place of residence at the time of the accident. No relationship was found. Positive AMC titers were found relatively frequently (2.9%) in girls in areas with ^{137}Cs contamination level in the range from 5 to 10 Ci/km^2 at the time of the accident. No relationship between the positive titers of AMC antibodies and ^{137}Cs contamination level in the place of residence of the children examined was established (Figure 14).

Table 4 shows the qualitative distribution of children based on the results of the investigations of thyroid function relative to sex and place of residence. A total of 15

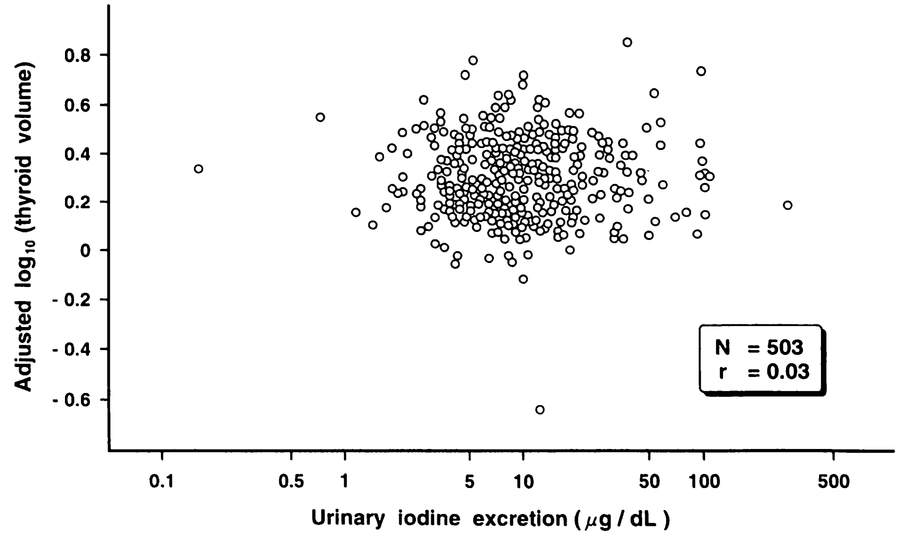

Figure 15. Scatter plots of urinary iodine excretion and the residual of the logarithm of thyroid volume after adjustment for age, height and weight.

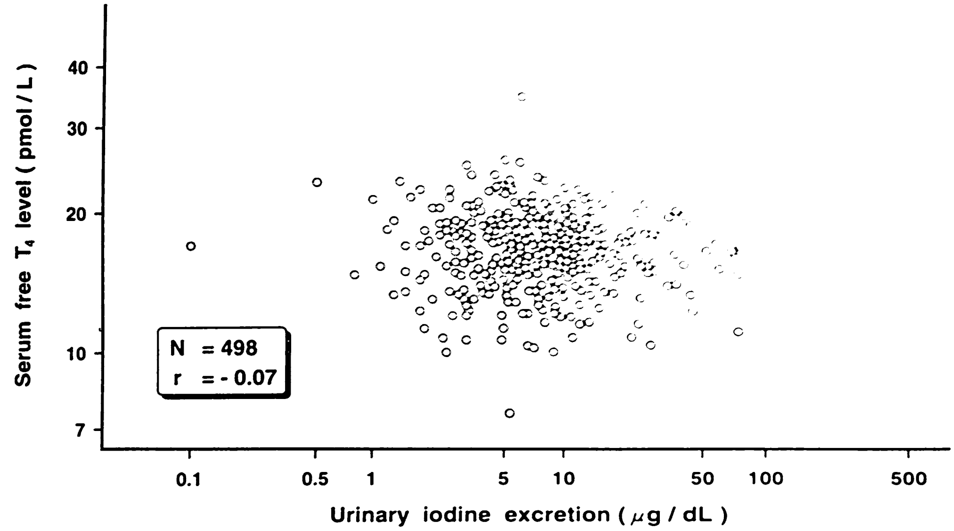

Figure 16. Scatter plots of urinary iodine excretion and serum free T_4 level.

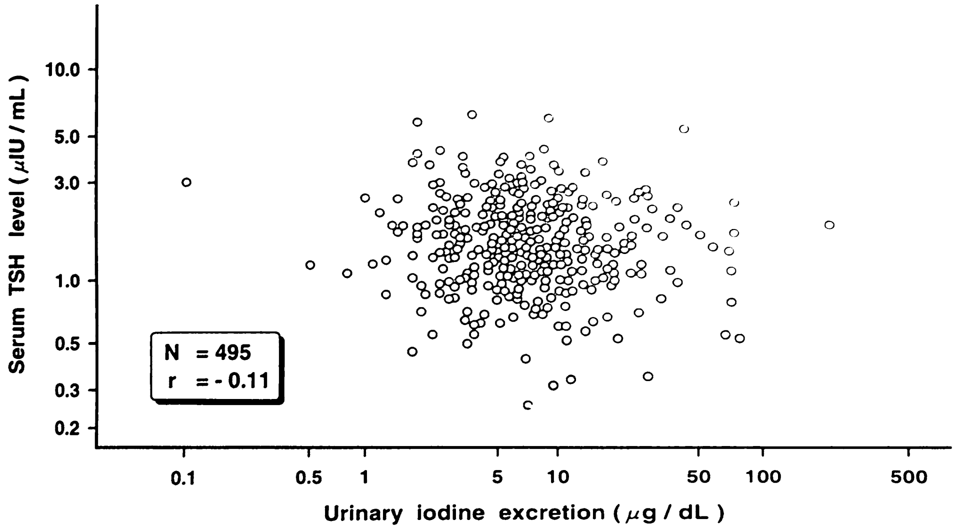

Figure 17. Scatter plots of urinary iodine excretion and serum TSH level.

children (6 boys and 9 girls) were found to be hypothyroidism and 9 children (2 boys and 7 girls) to be hyperthyroidism. As shown in the table girls suffered from thyroid function disorders more frequently than boys.

The relationship between urinary iodine content and the residual of thyroid volume after adjustment for age, height and weight and concentration of serum FT_4 and TSH was studied (Figures 15–17). A low but statistically significant negative correlation was observed between urinary iodine content and TSH level: the 95% confidence interval of the correlation coefficient was $-0.2 < \rho < -0.02$. However, no significant correlation was observed between urinary iodine content and the residual thyroid volume or FT_4 content. A similar analysis was conducted for ^{137}Cs specific activity in the body. A statistically significant positive correlation was found between ^{137}Cs specific activity and residual thyroid volume and FT$_4$ content, and a statistically significant negative correlation was observed between ^{137}Cs specific activity and TSH. However, all of the estimated correlation coefficients were small.

3.4 Hematological studies

Figure 18 shows the relationship between Hb level in peripheral blood samples and sex and age. The median of Hb was within the normal range. Hb level increased with age. Children under 12 years of age (boys and girls) showed similar Hb median levels. Hb level increased in boys above 13 years old, but girls of 16 years old showed a minor decrease in Hb level.

Figure 19 shows the relationship between MCV and sex and age. The median of MCV was within normal limits and increased with age. The median levels were slightly lower among boys than among girls in all age groups. Girls of 16 years old, however, showed also a slight decrease in MCV level.

Figure 20 shows the relationship between PLT and sex and age. PLT level decreased with age, but girls about 16 years old showed an increase in PLT. The median of PLT was within the normal limits.

Figure 21 shows the relationship between WBC in peripheral blood samples and age and sex. WBC did not correlate with sex or age and was within normal limits. An increase in WBC in peripheral blood in all age groups was noted in children with infectious diseases at the time of the examination.

Figure 22 shows the relationship between neutrophils and sex and age. The absolute count of neutrophils in peripheral blood was within the normal limits. The me-

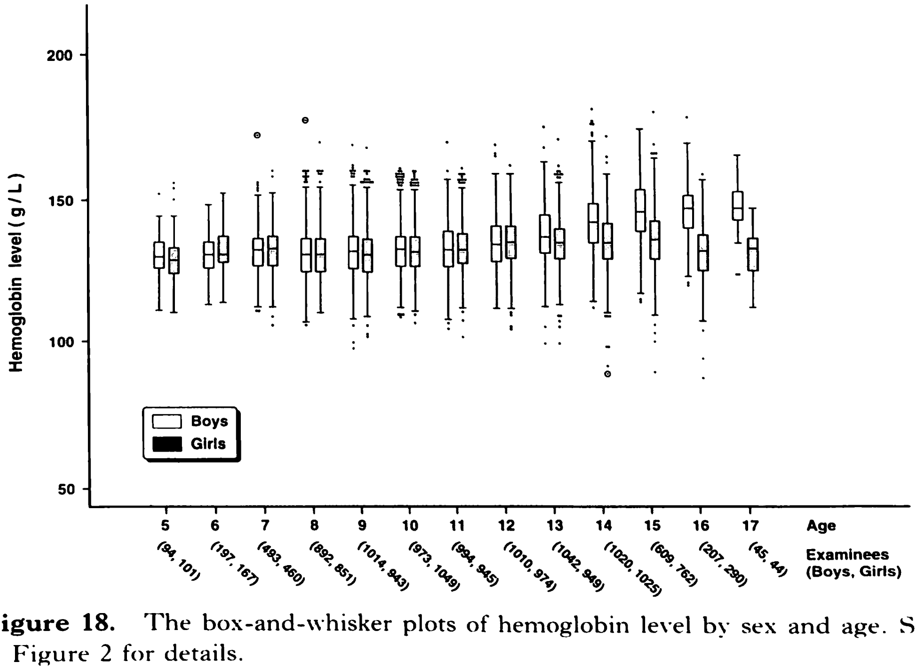

Figure 18. The box-and-whisker plots of hemoglobin level by sex and age. See Figure 2 for details.

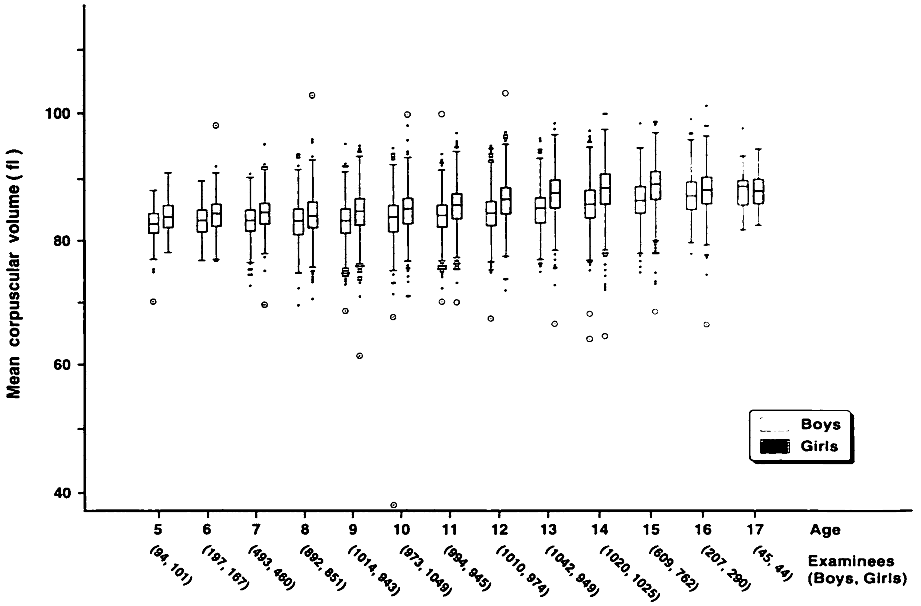

Figure 19. The box-and-whisker plots of mean corpuscular volume by sex and age. See Figure 2 for details.

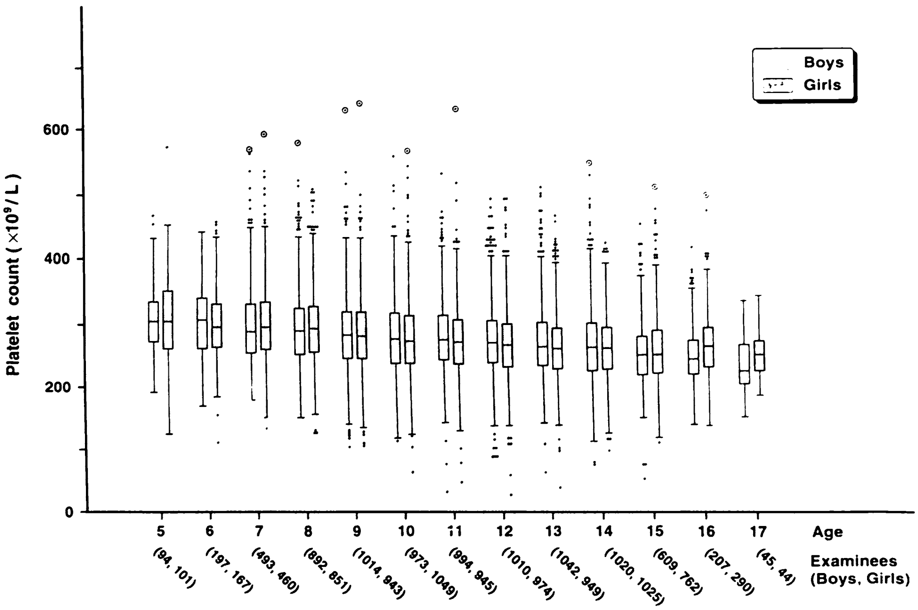

Figure 20. The box-and-whisker plots of platelet count by sex and age. See Figure 2 for details.

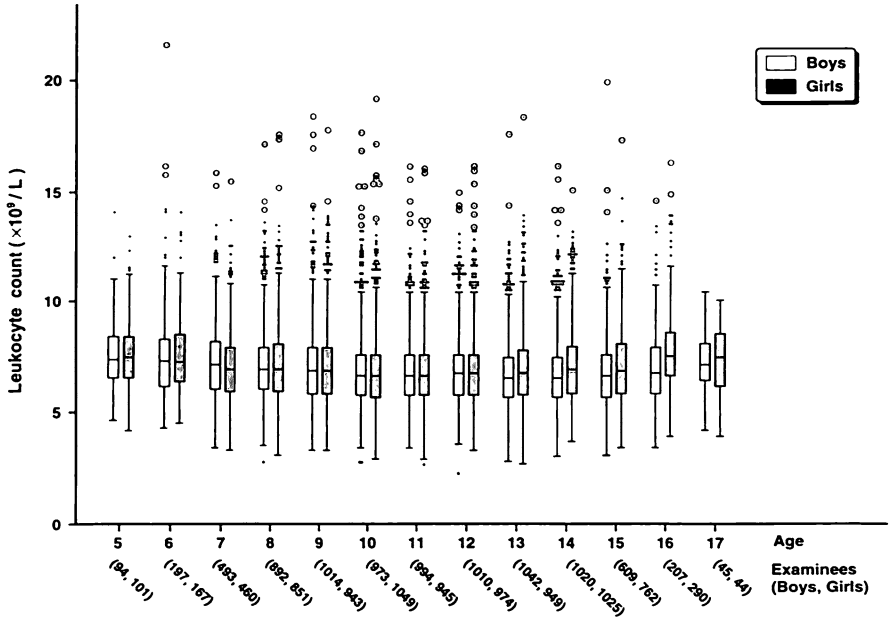

Figure 21. The box-and-whisker plots of leukocyte count by sex and age. See Figure 2 for details.

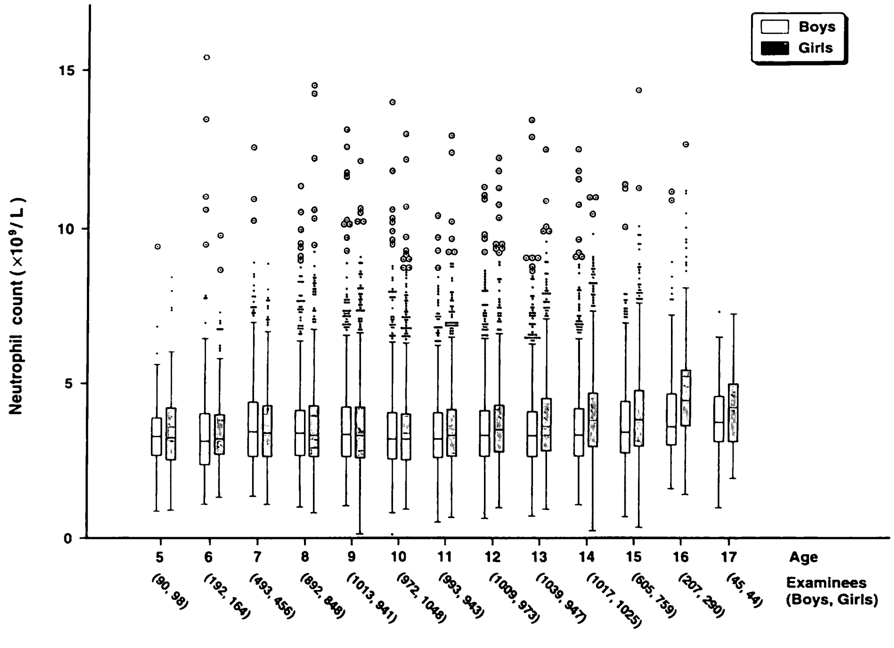

Figure 22. The box-and-whisker plots of neutrophil count by sex and age. See Figure 2 for details.

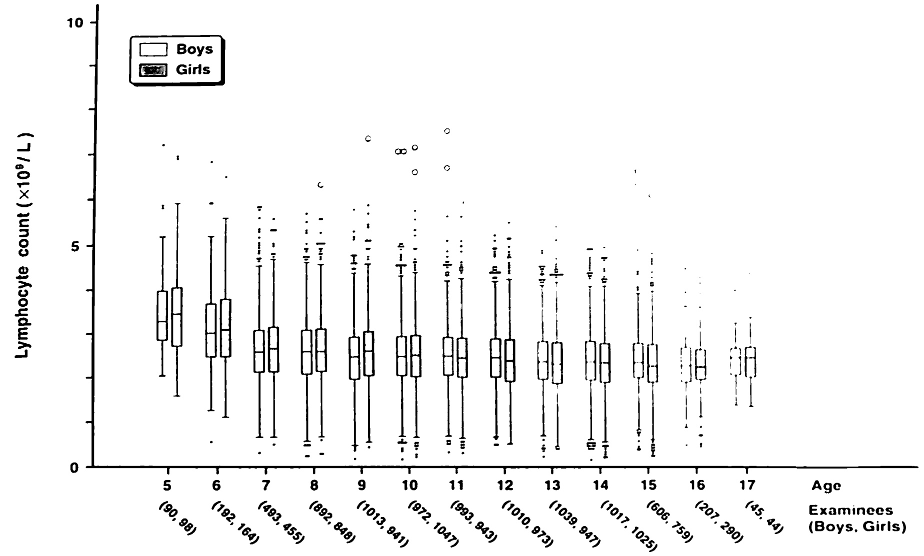

Figure 23. The box-and-whisker plots of lymphocyte count by sex and age. See Figure 2 for details.

dian of neutrophils in children of 5–6 years of age (in both boys and girls) was lower than in children of different ages.

Figure 23 shows the relationship of lymphocyte count in peripheral blood and sex and age in the children examined. The highest medians in lymphocyte count were observed in children of 5–6 years old. There was a trend toward a decrease in lymphocyte count in the children examined from 7 years of age.

Table 5A shows the hematological deviations from normal limits in boys in relation to the place of residence. The highest percentage of hematological abnormality was observed for eosinophilia (20.2%). A decrease in MCV was registered in 9.7% of all children but in 31.3% of children from Gordeevskii Rayon. The mean ^{137}Cs specific activity in these children was 203.5 Bq/kg, and the ^{137}Cs contamination level in the place of residence was higher than 15 Ci/km^2. Lymphocytosis was found in 8.3% of the children.

Table 5B shows the hematological deviations from the normal limits among girls in relation to the place of residence. A high frequency of elevated eosinophil count was noted in girls. The decrease in MCV was registered less frequently in girls than in boys (twice as low as in boys). However, it should be noted that a considerable number of girls from Gordeevskii Rayon showed low levels of MCV (19.8%). The frequency of deviations in other parameters was the same as in boys.

Tables 6A and 6B show the hematological deviations from the normal limits in boys and girls in relation to ^{137}Cs specific activity. A high frequency of decreased MCV was observed in conjunction with an increase in ^{137}Cs specific activity in both boys and girls, suggesting that the increase in ^{137}Cs specific activity in girls and boys gives rise to low MCV. The frequency of low MCV was 7.4% and 16.6% in boys with ^{137}Cs specific activity ranging from 0 to 50 Bq/kg and from 200 to 500 Bq/kg, respectively.

Table 5A. Frequency of boys with hematological abnormalities by place of residence.[a]

Blood analysis		Place of residence[b]					Total
Item (unit)[c]	Abnormality criteria	KLR	KLC	NVZ	ZLN	GOR	
Hb (g/L)	< 110		7	2		5	14
			(0.1)	(0.2)		(0.8)	(0.2)
	> 180		1				1
			(0.0)				(0.0)
WBC ($\times 10^9$/L)	< 3.8	5	33	10	5	3	56
		(0.4)	(0.7)	(0.8)	(0.7)	(0.5)	(0.6)
	> 10.6	46	121	46	24	19	256
		(3.9)	(2.5)	(3.5)	(3.1)	(3.2)	(3.0)
PLT ($\times 10^9$/L)	< 100	1	3	5			9
		(0.1)	(0.1)	(0.4)			(0.1)
	> 440	9	49	14	15	2	89
		(0.8)	(1.0)	(1.1)	(2.0)	(0.3)	(1.0)
MCV (fl)	< 80	107	339	105	103	187	841
		(9.1)	(7.1)	(7.9)	(13.4)	(31.3)	(9.7)
	> 100		1	1			2
			(0.0)	(0.1)			(0.0)
Ly ($\times 10^9$/L)	< 1.2	69	302	19	14	12	416
		(5.9)	(6.3)	(1.4)	(1.8)	(2.0)	(4.8)
	> 3.5	98	387	118	66	51	720
		(8.3)	(8.1)	(8.9)	(8.6)	(8.5)	(8.3)
Ne ($\times 10^9$/L)	< 1.4	8	49	13	6	2	78
		(0.7)	(1.0)	(1.0)	(0.8)	(0.3)	(0.9)
	> 6.6	50	162	50	25	30	317
		(4.3)	(3.4)	(3.8)	(3.3)	(5.0)	(3.7)
Eo ($\times 10^9$/L)	> 0.5	300	1015	233	96	101	1745
		(25.6)	(21.3)	(17.5)	(12.5)	(16.9)	(20.2)
Mo ($\times 10^9$/L)	< 0.12	32	286	17	7	5	347
		(2.7)	(6.0)	(1.3)	(0.9)	(0.8)	(4.0)
	> 1.00	45	194	44	30	19	332
		(3.8)	(4.1)	(3.3)	(3.9)	(3.2)	(3.8)
Number of children measured		1174	4762	1328	768	598	8630

[a] Parenthetic entries refer to the percentage of the subjects while empty spaces denote the absence of subjects with abnormalities.

[b] KLR, Klintsovskii; KLC, Klincy City; NVZ, Novozybkovskii; ZLN, Zlynkovskii; GOR, Gordeevskii.

[c] Hb, hemoglobin; WBC, white blood cell (leukocyte); PLT, platelet; MCV, mean corpuscular volume; Ly, lymphocyte; Ne, neutrophil; Eo, eosinophil; Mo, monocyte.

The frequency of low MCV in girls was 3.4% in the range of 0–50 Bq/kg and 10.8% in the range of 200–500 Bq/kg. Low MCV levels in the range higher than 500 Bq/kg were found in 2.8% of boys and in 10.8% of girls.

A statistically significant correlation was observed between the eosinophil count and platelets: 95% confidence interval of the correlation coefficient was $0.27 < \rho < 0.29$.

One child from Klincy City (where the contamination level is 7.33 Ci/km^2) was found to have acute myeloblastic leukemia (AML) three months after screening. At the time of the examination at the Sasakawa Laboratory the child showed absolute lymphocytosis and eosinophilia, but at the time of re-examination by a pediatrician no pathologic changes were found in the internal organs. The ^{137}Cs specific activity was 23.1 Bq/kg at the time of the examination. Treatment was conducted to no effect, and

Table 5B. Frequency of girls with hematological abnormalities by place of residence.[a]

Blood analysis		Place of residence[b]					Total
Item (unit)[c]	Abnormality criteria	KLR	KLC	NVZ	ZLN	GOR	
Hb (g/L)	< 110	5	12	4	4	3	28
		(0.4)	(0.3)	(0.3)	(0.5)	(0.5)	(0.3)
	> 160	5	11			1	17
		(0.4)	(0.2)			(0.2)	(0.2)
WBC ($\times 10^9$/L)	< 3.6	6	11	9	2		28
		(0.5)	(0.2)	(0.7)	(0.2)		(0.3)
	> 11.0	38	91	37	24	36	226
		(3.2)	(2.0)	(2.8)	(2.9)	(5.9)	(2.6)
PLT ($\times 10^9$/L)	< 100		2	1		1	4
			(0.0)	(0.1)		(0.2)	(0.0)
	> 440	17	33	13	7	3	73
		(1.4)	(0.7)	(1.0)	(0.8)	(0.5)	(0.9)
MCV (fl)	< 80	47	155	45	55	121	423
		(4.0)	(3.3)	(3.4)	(6.7)	(19.8)	(4.9)
	> 100		3		1		4
			(0.1)		(0.1)		(0.0)
Ly ($\times 10^9$/L)	< 1.2	83	295	21	7	9	415
		(7.0)	(6.4)	(1.6)	(0.8)	(1.5)	(4.8)
	> 3.5	97	392	107	65	57	718
		(8.2)	(8.5)	(8.2)	(7.9)	(9.3)	(8.4)
Ne ($\times 10^9$/L)	< 1.4	10	60	19	8	5	102
		(0.8)	(1.3)	(1.4)	(1.0)	(0.8)	(1.2)
	> 6.6	67	195	63	38	44	407
		(5.6)	(4.2)	(4.8)	(4.6)	(7.2)	(4.7)
Eo ($\times 10^9$/L)	> 0.5	247	942	233	115	101	1638
		(20.8)	(20.3)	(17.8)	(13.9)	(16.5)	(19.1)
Mo ($\times 10^9$/L)	< 0.12	43	285	28	6	6	368
		(3.6)	(6.1)	(2.1)	(0.7)	(1.0)	(4.3)
	> 1.00	42	163	34	14	29	282
		(3.5)	(3.5)	(2.6)	(1.7)	(4.7)	(3.3)
Number of children measured		1188	4637	1312	827	611	8575

[a] Parenthetic entries refer to the percentage of the subjects while empty spaces denote the absence of subjects with abnormalities.

[b] KLR, Klintsovskii; KLC, Klincy City; NVZ, Novozybkovskii; ZLN, Zlynkovskii; GOR, Gordeevskii.

[c] Hb, hemoglobin; WBC, white blood cell (leukocyte); PLT, platelet; MCV, mean corpuscular volume; Ly, lymphocyte; Ne, neutrophil; Eo, eosinophil; Mo, monocyte.

the child died. Three children from Klincy City and one child from Gordeevskii Rayon were shown to have Pelger anomaly, but the state of health was satisfactory.

An attempt to study seasonal differences in the prevalence of eosinophilia was made because many children were found to have a high eosinophil count. But it is difficult to find any seasonal prevalence of eosinophilia because the number of re-examined children was small.

An analysis was conducted on deviations from normal hematological limits. The results are presented in Table 7.

Figure 24 shows the ferritin values in boys and girls with normal MCV and Hb in age groups from 5 to 16 years old. Figure 25 shows the ferritin values in children with low Hb (< 110 g/L). The correlation coefficient was 0.4. Figure 26 shows the ferritin concentration in children with low MCV (< 80 fl). The correlation coefficient was 0.3.

Table 6A. Frequency of boys with hematological abnormalities by ^{137}Cs level.[a]

Blood analysis		Whole body ^{137}Cs count per body weight (Bq/kg)					Total
Item (unit)[b]	Abnormality criteria	0–50	50–100	100–200	200–500	500–	
Hb (g/L)	< 110	3 (0.1)	4 (0.2)	5 (0.4)	2 (0.3)		14 (0.2)
	> 180	1 (0.0)					1 (0.0)
WBC (x10^9/L)	< 3.8	27 (0.6)	17 (0.8)	5 (0.4)	7 (0.9)		56 (0.6)
	> 10.6	122 (2.8)	68 (3.2)	34 (2.5)	31 (4.0)	1 (0.8)	256 (3.0)
PLT (x10^9/L)	< 100	1 (0.0)	1 (0.0)	5 (0.4)	1 (0.1)	1 (0.8)	9 (0.1)
	> 440	47 (1.1)	17 (0.8)	16 (1.2)	8 (1.0)	1 (0.8)	89 (1.0)
MCV (fl)	< 80	317 (7.4)	213 (10.2)	171 (12.6)	128 (16.6)	12 (9.4)	841 (9.7)
	> 100	1 (0.0)	1 (0.0)				2 (0.0)
Ly (x10^9/L)	< 1.2	249 (5.8)	99 (4.7)	49 (3.6)	18 (2.3)	1 (0.8)	416 (4.8)
	> 3.5	318 (7.4)	197 (9.4)	115 (8.5)	78 (10.1)	12 (9.4)	720 (8.3)
Ne (x10^9/L)	< 1.4	52 (1.2)	14 (0.7)	9 (0.7)	3 (0.4)		78 (0.9)
	> 6.6	152 (3.6)	88 (4.2)	44 (3.3)	32 (4.1)	1 (0.8)	317 (3.7)
Eo (x10^9/L)	> 0.5	897 (21.0)	432 (20.6)	256 (18.9)	131 (17.0)	29 (22.8)	1745 (20.2)
Mo (x10^9/L)	< 0.12	201 (4.7)	93 (4.4)	35 (2.6)	16 (2.1)	2 (1.6)	347 (4.0)
	> 1.00	176 (1.5)	87 (4.1)	40 (3.0)	26 (3.5)	2 (1.6)	332 (3.8)
Number of children measured		4281	2097	1353	772	127	8630

[a] Parenthetic entries refer to the percentage of the subjects while empty spaces denote the absence of subjects with abnormalities.

[b] Hb, hemoglobin; WBC, white blood cell (leukocyte); PLT, platelet; MCV, mean corpuscular volume; Ly, lymphocyte; Ne, neutrophil; Eo, eosinophil; Mo, monocyte.

Table 6B. Frequency of girls with hematological abnormalities by ^{137}Cs level.[a]

Blood analysis		Whole body ^{137}Cs count per body weight (Bq/kg)					Total
Item (unit)[b]	Abnormality criteria	0–50	50–100	100–200	200–500	500–	
Hb (g/L)	< 110	14 (0.3)	4 (0.2)	3 (0.2)	6 (0.9)	1 (0.9)	28 (0.3)
	> 160	12 (0.3)	4 (0.2)			1 (0.9)	17 (0.2)
WBC (x10^9/L)	< 3.6	17 (0.4)	6 (0.3)	4 (0.3)	1 (0.1)		28 (0.3)
	> 11.0	111 (2.4)	45 (2.3)	44 (3.6)	25 (3.7)	1 (0.9)	226 (2.6)
PLT (x10^9/L)	< 100	3 (0.1)		1 (0.1)			4 (0.0)
	> 440	43 (0.9)	18 (0.9)	6 (0.5)	5 (0.7)	1 (0.9)	73 (0.9)
MCV (fl)	< 80	157 (3.4)	97 (5.0)	93 (7.6)	73 (10.8)	3 (2.8)	423 (4.9)
	> 100	1 (0.0)	1 (0.1)	2 (0.2)			4 (0.0)
Ly (x10^9/L)	< 1.2	292 (6.3)	81 (4.2)	27 (2.2)	13 (1.9)	2 (1.9)	415 (4.8)
	> 3.5	363 (7.8)	185 (9.7)	111 (9.1)	49 (7.3)	10 (9.3)	718 (8.4)
Ne (x10^9/L)	< 1.4	55 (1.2)	22 (1.1)	9 (0.7)	12 (1.8)	4 (3.7)	102 (1.2)
	> 6.6	209 (4.5)	87 (4.5)	68 (5.6)	40 (5.9)	3 (2.8)	407 (4.7)
Eo (x10^9/L)	> 0.5	900 (19.4)	366 (19.0)	241 (19.7)	117 (17.4)	14 (13.1)	1638 (19.1)
Mo (x10^9/L)	< 0.12	219 (14.7)	101 (5.3)	29 (2.4)	18 (2.7)	1 (0.9)	368 (4.3)
	> 1.00	159 (3.4)	57 (3.0)	45 (3.7)	20 (3.0)	1 (0.9)	282 (3.3)
Number of children measured		4647	1922	1225	674	107	8575

[a] Parenthetic entries refer to the percentage of the subjects while empty spaces denote the absence of subjects with abnormalities.

[b] Hb, hemoglobin; WBC, white blood cell (leukocyte); PLT, platelet; MCV, mean corpuscular volume; Ly, lymphocyte; Ne, neutrophil; Eo, eosinophil; Mo, monocyte.

Table 7. Results of re-examination of children found to have hematological abnormalities at the screening.

Blood analysis		Number of children with abnormalities at screening	Number of children undergoing re-examination	Results of re-examination
Item (unit)[a]	Abnormality criteria			
Hb (g/L)	< 110	42	11	8 - normal 3 - iron deficiency anemia
WBC ($\times 10^9$/L)	< 3.8 for boys < 3.6 for girls	84	33	30 - normal 3 - leukopenia (without clinical manifestation)
PLT ($\times 10^9$/L)	< 100	13	4	4 - normal
Eo ($\times 10^9$/L)	> 0.5	3383	1213	791 - normal 422 - eosinophilia, induced by allergic and parasitic diseases

[a] Hb, hemoglobin; WBC, white blood cell (leukocyte); PLT, platelet; Eo, eosinophil.

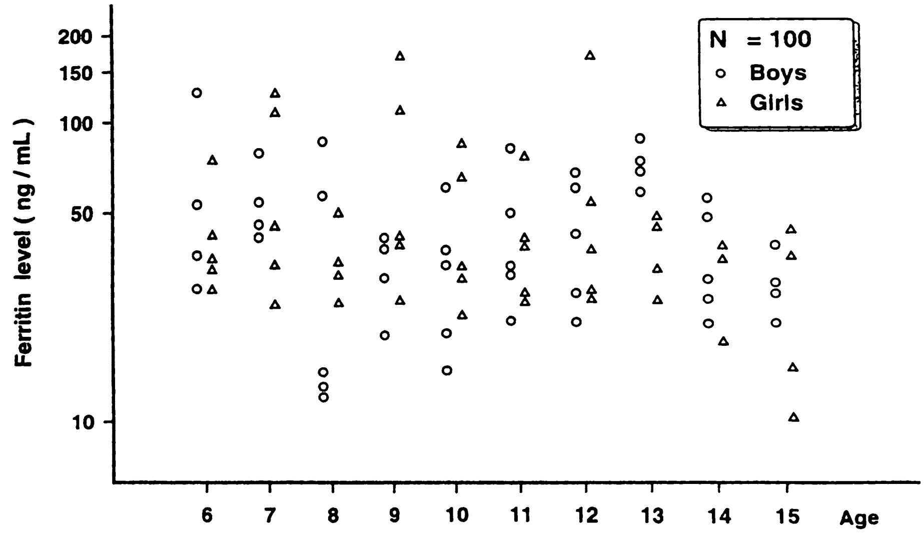

Figure 24. Distribution of ferritin level by age and sex in hematologically normal children.

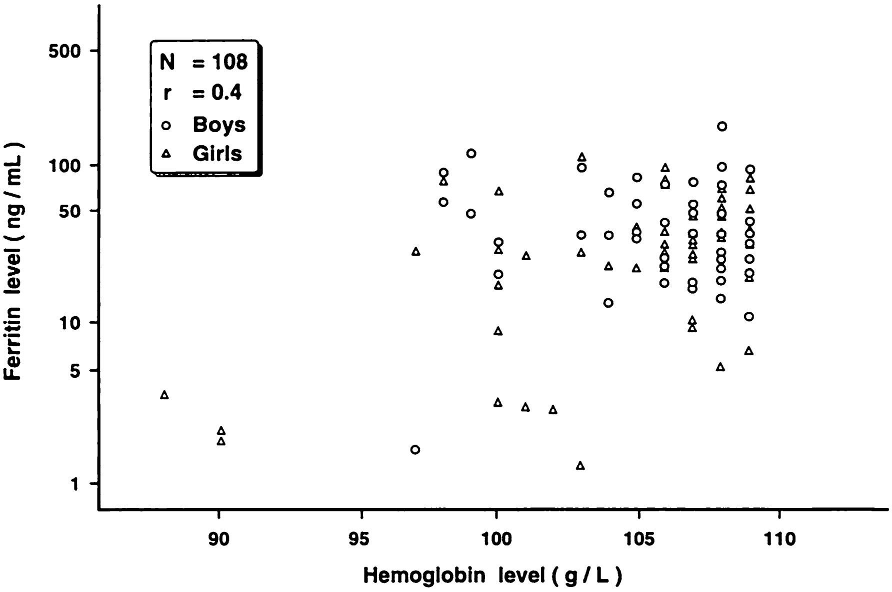

Figure 25. Scatter plots of hemoglobin (Hb) and ferritin levels in children with Hb less than 110 g/L.

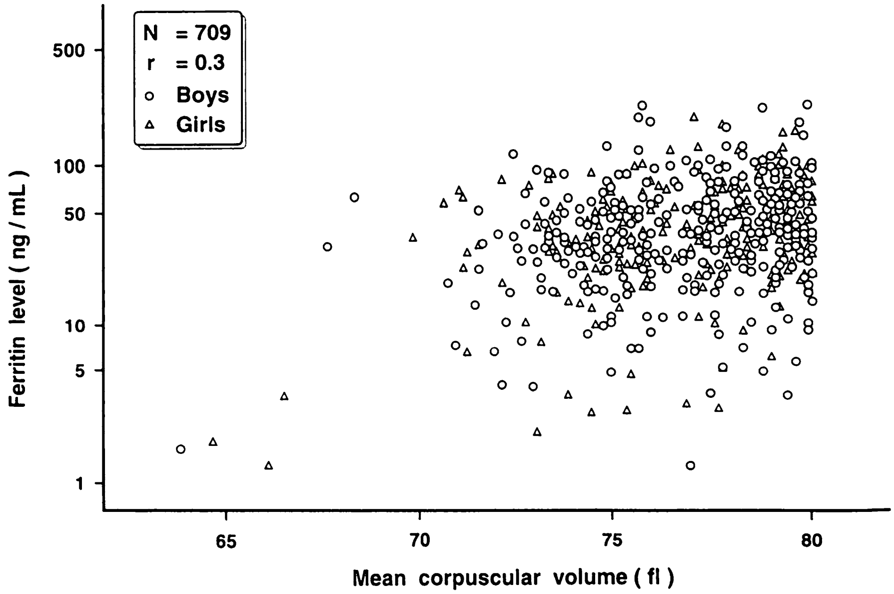

Figure 26. Scatter plots of mean corpuscular volume (MCV) and ferritin levels in children with MCV less than 80 fl.

4. Conclusions

The majority of ^{137}Cs specific activity values ranged from 50 to 100 Bq/kg and were independent of age and sex.

A high ^{137}Cs specific activity level was noted among children residing in a considerable number of locations in Gordeevskii and Novozybkovskii Rayons where ^{137}Cs contamination level exceeds 15 Ci/km^2.

The prevalence of goiter in boys increased with the increase in the ^{137}Cs contamination level in the place of residence at the time of the accident. Goiter was found more frequently in children who lived in the area with a ^{137}Cs contamination level ranging from 15 to 20 Ci/km^2 at the time of the accident.

Four cases of thyroid cancer was diagnosed in children born in the period of 1981–1986 in the course of the Chernobyl Sasakawa Project during 1993–1994.

A high frequency of elevated eosinophil count was registered during peripheral blood testing.

Children from Gordeevskii Rayon showed a high percentage of low MCV (< 80 fl). Children from this rayon were found to have the highest ^{137}Cs specific activity (200 Bq/kg). An increase in ^{137}Cs specific activity in the intervals from 0–50 to 200–500 Bq/kg gave rise to a higher prevalence of low MCV, but did not to the prevalence of anemia. The cause of the low MCV remains to be elucidated.

Results of the Examination of Children in Kiev Oblast

Kiev Regional Hospital No. 2
"Sasakawa-Chernobyl" Diagnostic Center

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1. Introduction

The five-year program of the Sasakawa Chernobyl Project was launched in 1991. In Kiev Oblast (Province), the program is implemented by the Diagnostic Center at the Regional Hospital No. 2. Investigations concerning the effects of the Chernobyl Nuclear Power Plant accident on the health status of children is vitally important, especially for those residing in Kiev Oblast where the epicenter of the disaster lies. More than 2/3 of the territory of the oblast was exposed to $^{134-137}$Cs contamination ranging from 1 to 40 Ci/km^2 and higher (Figure 1). Moreover, the largest part of the territory is endemic goiter due to a low iodine content in the biosphere. More than 220,000 children were exposed to various doses of radiation, and the results of prophylactic medical examinations show that their health status has deteriorated.

The thyroid abnormality is important for the assessment of health status because the thyroid gland is 10 times more sensitive to radiation effects in children than in adults. About 400 radionuclides were emitted into the atmosphere as a result of the disaster, and radioactive iodines accounted for 20% of the total. The follicles of the thyroid gland accumulate these radioisotopes, causing the dysfunction of the thyroid. With its intense blood supply, the thyroid gland bears a dose burden not only due to radioactive iodine but also due to other elements such as ^{137}Cs and ^{134}Cs. More than 60,000 children have a thyroid dose up to 0.3 Gy, and 6,000 between 0.3 and 3.2 Gy. The results of the examination of 18,000 children in the Sasakawa Chernobyl program were analyzed.

2. Materials and Methods

2.1 Study subjects

The subjects under study are children born between 26 April 1976 and 26 April 1986 and residing in the exposed areas of Kiev Oblast. The investigation was carried out in accordance with the method implemented at all 5 centers and using the facilities provided by the Sasakawa Foundation (a mobile laboratory and stationary equipment).

2.2 Measurement of whole body ^{137}Cs concentration

The whole body ^{137}Cs concentration was measured using the method suggested by

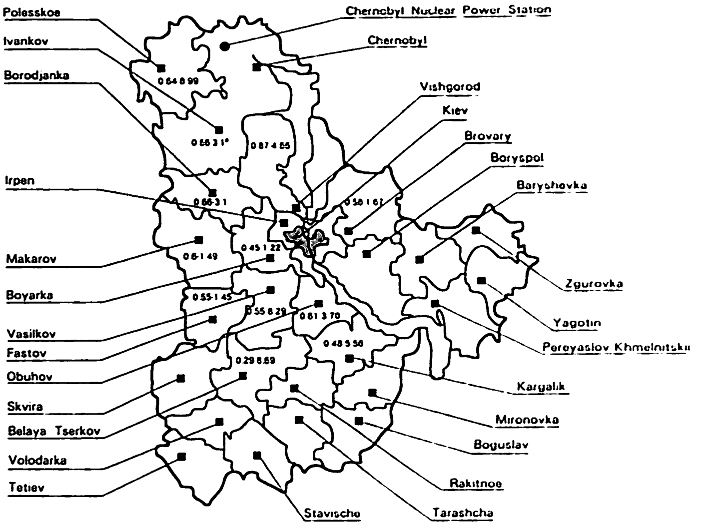

Figure 1. $^{137,134}Cs$ contamination levels (Ci/km^2) in the rayons of Kiev Oblast as measured in 1994. The black circle indicates the location of the Chernobyl Nuclear Power Station while the black squares (except one for Chernobyl) indicate the capitals of the respective rayons. For example, Vishgorod is the capital of Vishgorod*skii* Rayon.

[a] Minimum and maximum levels of contamination.

Japanese specialists. This method involves direct spectrometry of radionuclide activity and is carried out using a whole body counter (WBC-101) manufactured by Aloka Company (Japan).

2.3 Thyroid examinations

The thorough examination of the thyroid gland consists of ultrasound investigation, assay of the titers of anti-microsome antibodies (AMC) and anti-thyroglobulin antibodies (ATG) as well as the determination of the serum levels of thyroid stimulating hormone (TSH) and free T_4 (FT_4). These tests were carried out with an Amerlite analyzer using standard kits. The following criteria were used to assess the state of the thyroid gland: the structure and volume of the thyroid, levels of FT_4 and TSH, positive titers of anti-thyroglobulin (ATG) and anti-microsome (AMC) antibodies in the serum.

2.4 Hematological studies

Hematological studies were carried out using K-1000 and NE-7000 hemoanalyzers manufactured by Sysmex Company. The following eight parameters were analyzed: white blood cell count (WBC); red blood cell count (RBC); platelet count (PLT); mean corpuscular volume (MCV); hemoglobin concentration (Hb); mean corpuscular hemoglobin concentration (MCHC); mean corpuscular hemoglobin (MCH) and hematocrit (Ht).

The differential leukocyte count was analyzed with an Olympus-BH-2 microscope and NE-7000 analyzer.

3. Results

3.1 Study subjects

A total of 18,848 children residing in 19 rayons of Kiev Oblast and Kiev City were examined in the period from 15 May 1991 to 31 December 1994. The children live in the territories with a ^{137}Cs contamination level ranging from 0.5 to 40 Ci/km^2. Children aged 10 to 14 comprise the main group of subjects examined. Among the total number of children examined, 52.4% were girls and 47.6% were boys (Table 1).

Table 1. Classification of study subjects by sex and place of residence.[a]

Place of residence	Boys	Girls	Total
Vishgorodskii	1283 (10, 12, 14)	1321 (10, 12, 14)	2604 (10, 12, 14)
Polesskii	409 (8, 10, 12)	406 (8, 10, 12)	815 (8, 10, 12)
Borodyanskii	950 (9, 11, 13)	1010 (9, 11, 13)	1960 (9, 11, 13)
Makarovskii	423 (8, 10, 12)	516 (8, 10, 13)	939 (8, 10, 13)
Ivankovskii	634 (8, 10, 13)	624 (8, 10, 13)	1258 (8, 10, 13)
Kiev City	308 (9, 11, 13)	369 (10, 11, 13)	677 (9, 11, 13)
Irpenskii	932 (9, 12, 14)	1091 (10, 12, 14)	2023 (9, 12, 14)
Vasilkovskii	267 (9, 11, 14)	304 (10, 12, 14)	571 (10, 12, 14)
Baryshevskii	130 (9, 11, 13)	101 (9, 12, 13)	231 (9, 11, 13)
Svyatoshinskii	749 (10, 13, 15)	806 (10, 13, 15)	1555 (10, 13, 15)
Kagarlytskii	349 (10, 11, 14)	449 (10, 12, 14)	798 (10, 12, 14)
Fastovskii	230 (10, 12, 14)	397 (11, 13, 14)	627 (10, 12, 14)
Belotserkovskii	216 (10, 12, 14)	221 (9, 11, 13)	437 (9, 11, 13)
Brovarskii	723 (10, 11, 13)	767 (6, 11, 14)	1490 (9, 11, 14)
Borispolskii	156 (9, 11, 13)	141 (10, 11, 14)	297 (10, 11, 14)
Obukhovskii	341 (9, 11, 13)	324 (9, 11, 14)	665 (9, 11, 14)
Rakitnyanskii	485 (9, 11, 13)	588 (9, 12, 14)	1073 (9, 11, 14)
Stavischenskii	365 (10, 13, 14)	428 (10, 13, 15)	793 (10, 13, 14)
Mironovskii	9 (9, 12, 14)	14 (11, 12, 12)	23 (10, 11, 12)
P-Khmelnitskii	6 (10, 13, 15)	6 (10, 12, 14)	12 (11, 13, 14)
Total	8965 (9, 12, 14)	9883 (10, 12, 14)	18 848 (10, 12, 14)

[a] Each triplet gives the 25th, 50th and 75th sample percentiles of age distribution at the time of examination.

3.2 Measurement of whole body ^{137}Cs concentration

Figure 2 shows the relationship between the ^{137}Cs specific activity and sex and age among children examined in 1994. The children with whole body ^{137}Cs count less than the detection limit, i.e. 540 Bq, were excluded from the figure. The number of boys and girls excluded in each age group was as follows (girls in parentheses): 8-year, 270(261); 9-year, 300(345); 10-year, 329(330); 11-year, 296(281); 12-year, 282(312); 13-year, 281(328); 14-year, 294(350); 15-year, 151(219); 16-year, 77(141); and 17-year, 16(33). The median level of the ^{137}Cs specific activity was independent of sex and amounted to approximately 30–40 Bq/kg in all age groups. The maximum level was 3,200 Bq/kg registered in a 13 year-old boy.

Figure 3 shows the distribution of ^{137}Cs specific activity by place of residence among children examined from 1991 to 1994. The number of children excluded from the figure having whole body ^{137}Cs count less than 540 Bq was as follows: 840 in Vishgorodskii; 828 in Borodyanskii; 2 in Makarovskii; 219 in Ivankovskii Rayons; 196 in Kiev City; 917 in Irpenskii; 6 in Vasilkovskii; 40 in Baryshevskii; 405 in Svyatoshinskii; 3 in Kagarlytskii; 12 in Fastovskii; 23 in Belotserkovskii; 344 in Brovarskii; 10 in Borispolskii; 8 in Obukhovskii; 535 in Rakitnyanskii; and 395 in Stavischenskii Rayons. Children living in the northern rayons of Kiev Oblast located close to the Chernobyl zone, i.e. Polesskii, Vishgorodskii and Ivankovskii Rayons, had the largest concentration. Individual outliers of extreme values (1,000–3,200 Bq/kg)

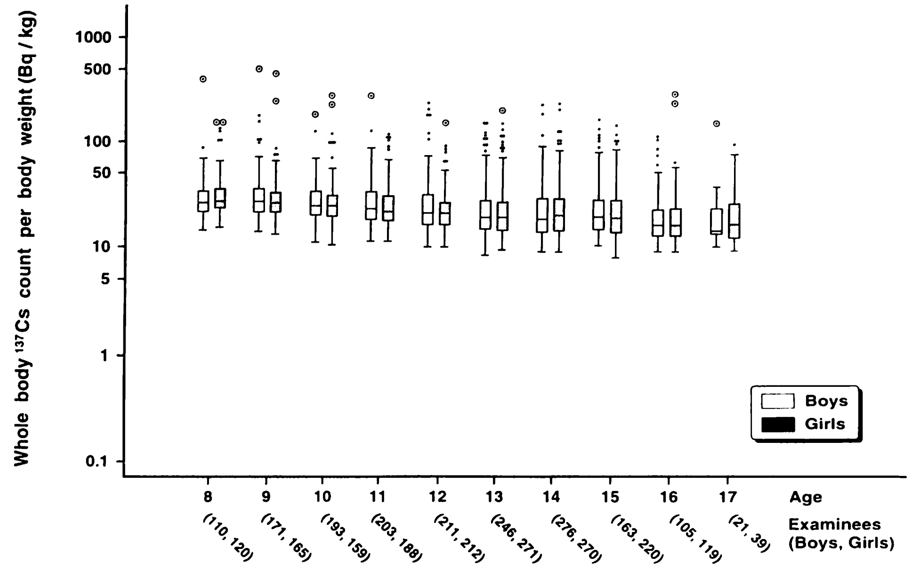

Figure 2. The box-and-whisker plots of whole body ^{137}Cs count per kg body weight by sex and age among children examined in 1994. The children with whole body ^{137}Cs count less than the detection limit (540 Bq) were excluded. The bottom and top ends of the box and the bar inside the box correspond to the 25th, 75th and 50th sample percentiles, respectively. The black dot and the double circle with black dot represent extreme values, called "outside" and "far out," respectively.

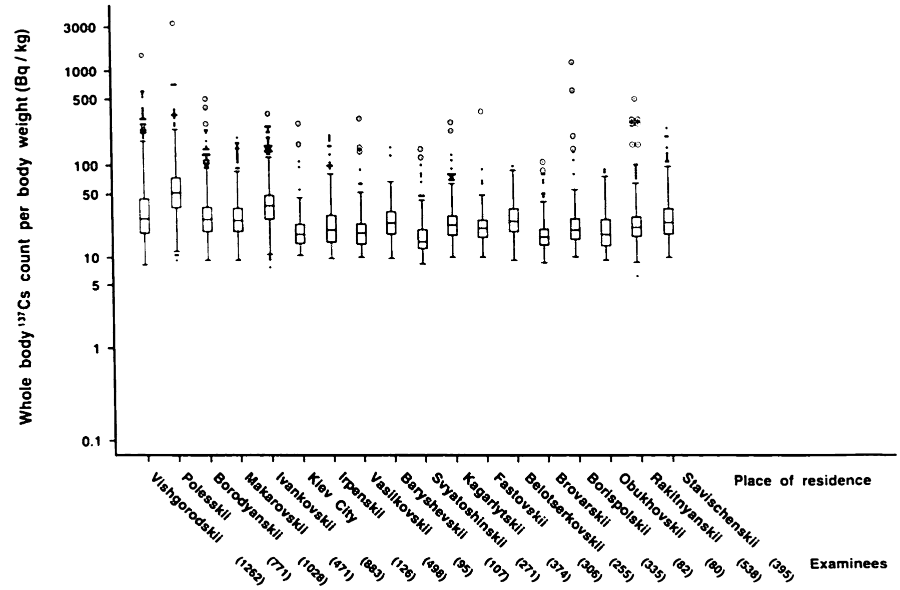

Figure 3. The box-and-whisker plots of whole body ^{137}Cs count per kg body weight by place of residence among children examined from 1991 to 1994. The children with whole body ^{137}Cs count less than the detection limit (540 Bq) were excluded. See Figure 2 for details.

were associated with visits to the contaminated areas and with the consumption of game, mushrooms and berries.

3.3 Thyroid examinations

Figure 4 shows the relationship between thyroid volume and age. The thyroid

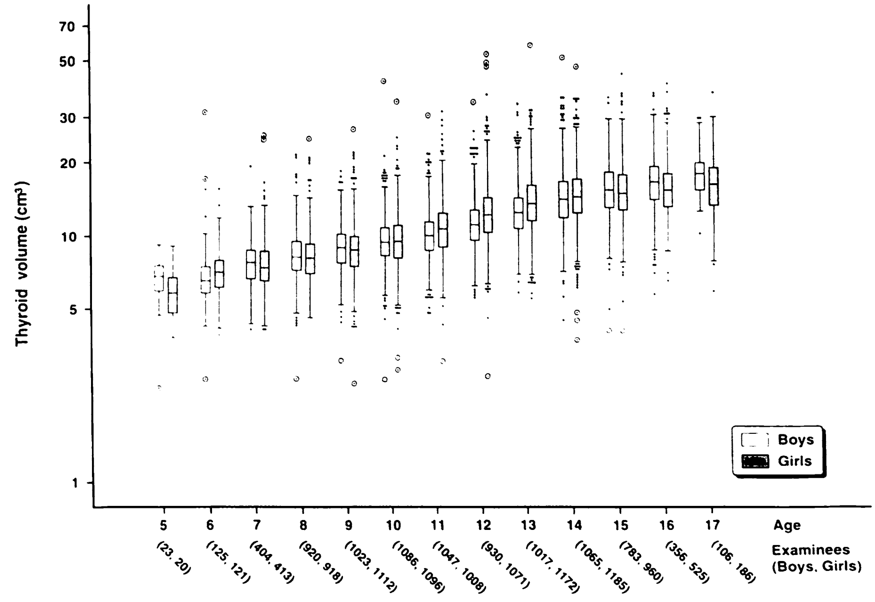

Figure 4. The box-and-whisker plots of thyroid volume by sex and age. See Figure 2 for details.

volume increased with age. Girls in the 11–14 year-old groups showed a larger thyroid volume than boys.

The highest frequency of goiter was registered in Brovarskii (81.0%), Fastovskii (71.1%) and Makarovskii (70.0%) Rayons, while the lowest frequency was observed in Borodyanskii Rayon (39.3%) (Figure 5). The prevalence of goiter in Kiev Oblast averaged 57.2% in girls and 52.7% in boys.

Figure 6 shows the prevalence of goiter by soil ^{137}Cs contamination level. No significant relationship was observed.

Figure 7 shows the prevalence of goiter by ^{137}Cs specific activity in the body. The number of cases with goiter increased with the increase in ^{137}Cs activity in the body and, it was 100% for the specific activity exceeding 500 Bq/kg. However, the data are statistically unreliable, because the number of children with such a high level of ^{137}Cs specific activity was small.

Our preliminary investigations on iodine content in water (114 samples) showed levels of 0.41 μg/dL in Brovarskii Rayon and 1.4 μg/dL in Irpenskii and Fastovskii Rayons. We studied the relationship between urinary iodine content, the residual of thyroid volume and serum FT$_4$ and TSH levels (Figures 8–10). A low but statistically significant correlation was observed between urinary iodine content and the residual thyroid volume (95% confidence interval of the correlation coefficient: $0.02 < \rho < 0.14$) and TSH level (95% confidence interval of the correlation coefficient: $-0.16 < \rho < -0.04$). However, no significant correlation was observed between urinary iodine content and FT$_4$ level.

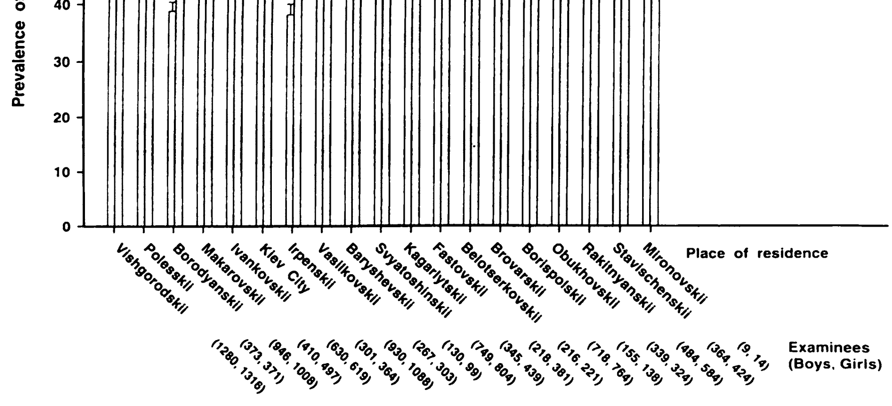

Figure 5. Prevalence of goiter by sex and place of current residence. The whiskers denote the standard errors. See page 2 for the definition of goiter.

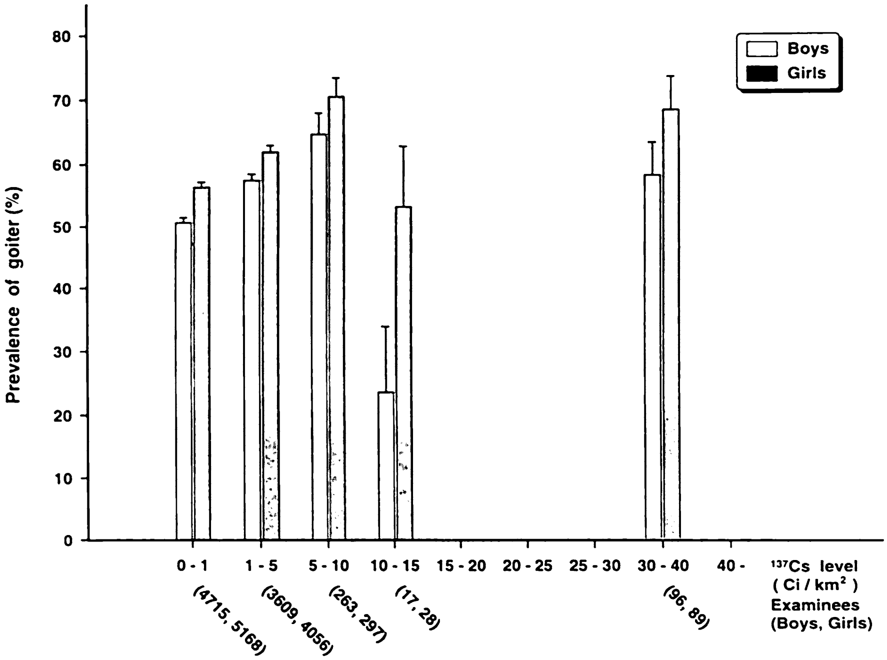

Figure 6. Prevalence of goiter by sex and contamination level (Ci/km^2) in the place of current residence. The whiskers denote the standard errors. See page 2 for the definition of goiter.

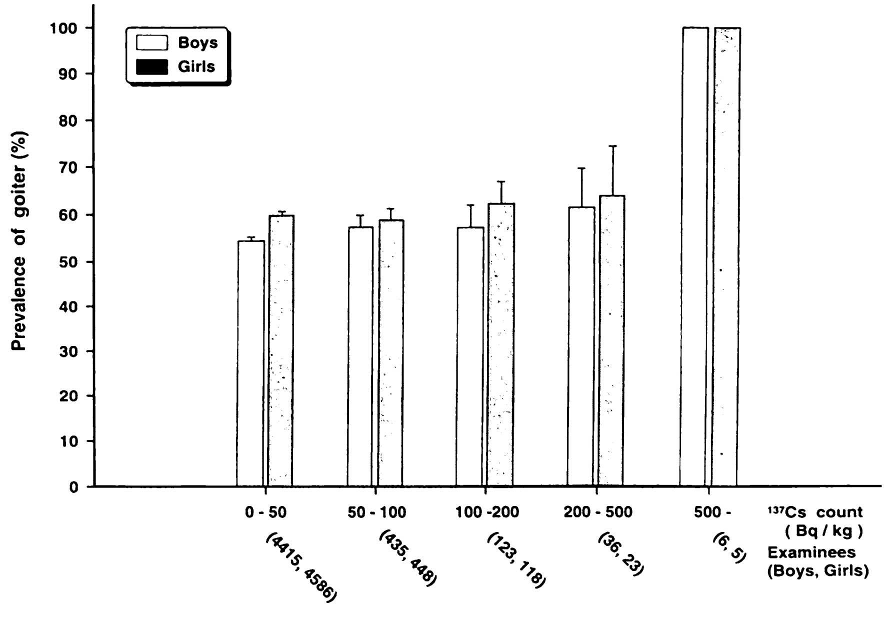

Figure 7. Prevalence of goiter by sex and whole body ^{137}Cs count per kg body weight. The whiskers denote the standard errors. See page 2 for the definition of goiter.

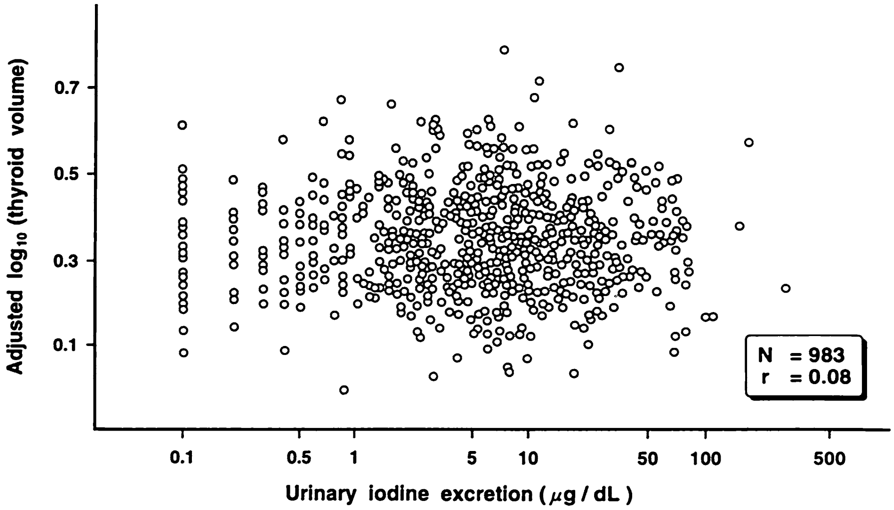

Figure 8. Scatter plots of urinary iodine excretion and the residual of the logarithm of thyroid volume after adjustment for age, height and weight.

Figure 9. Scatter plots of urinary iodine excretion and serum free T_4 level.

Figure 10. Scatter plots of urinary iodine excretion and serum TSH level.

Table 2 shows the results of ultrasound investigations of thyroid disorders. The commonest abnormality was registered in thyroid echogenity (452 children). Cysts were found in 26 children, anomaly in 5 children, and thyroid cancer in 4 children.

Table 3 shows the prevalence of positive ATG and AMC titers relative to place of residence and sex. The average prevalence of positive titers of ATG and AMC antibodies was 1.2% and 2.1%, respectively. Girls revealed positive titers of ATG and AMC antibodies (1.8 and 3.0%, respectively) more frequently than boys (0.6 and 1.2%, respectively). The prevalence of positive titers of ATG and AMC antibodies was approximately the same in all rayons, but it was slightly higher in Kiev City.

No correlation was observed between the prevalence of positive titers of ATG antibodies and ^{137}Cs specific activity in the body (Figure 11). No correlation was found either, between the prevalence of positive titers of AMC antibodies and ^{137}Cs specific activity in the body (Figure 12).

Table 2. Subjects with thyroid abnormalities by sex and place of residence.

Place of residence	Number of subjects examined		Diagnosis								
			Nodular lesion		Cystic lesion		Abnormal echogenity	Anomaly		Cancer	
	B[a]	G[a]	B	G	B	G	B and G	B	G	B	G
Vishgorodskii	1280	1316	1	1	1	2	91	2	1	0	0
Polesskii	373	371	0	0	0	0	0	0	0	0	0
Borodyanskii	946	1008	1	3	1	1	26	0	1	0	0
Makarovskii	410	497	1	1	0	0	29	0	0	0	1
Ivankovskii	630	619	1	1	0	1	5	0	0	0	0
Kiev City	301	364	1	1	3	1	20	0	0	0	1
Irpenskii	930	1088	0	2	3	2	57	0	1	0	1
Vasilkovskii	267	303	0	2	0	0	18	0	0	0	0
Baryshevskii	130	99	1	2	0	0	2	0	0	0	0
Svyatoshinskii	749	804	0	1	2	5	27	0	0	0	0
Kagarlytskii	345	439	0	0	1	0	11	0	0	0	0
Fastovskii	218	381	1	0	0	0	22	0	0	1	0
Belotserkovskii	216	221	1	1	1	1	17	0	0	0	0
Brovarskii	718	764	0	1	0	1	46	0	0	0	0
Borispolskii	155	138	0	0	0	1	10	0	0	0	0
Boguslavskii	3	5	0	0	0	0	0	0	0	0	0
Obukhovskii	339	324	0	2	3	1	27	0	0	0	0
Rakitnyanskii	484	584	2	0	1	0	25	0	0	0	0
Stavischenskii	364	424	1	1	0	0	25	0	0	0	0
Taraschanskii	3	3	0	0	0	0	1	0	0	0	0
Volodarskii	0	1	0	0	0	0	0	0	0	0	0
Zgurovskii	0	1	0	0	0	0	1	0	0	0	0
Mironovskii	9	14	0	0	0	0	0	0	0	0	0
Skvirskii	4	6	0	0	0	0	0	0	0	0	0
Tetievskii	2	1	0	0	0	0	1	0	0	0	0
Yagotinskii	3	7	0	0	0	0	0	0	0	0	0
P-Khmelnitskii	5	6	0	0	0	0	2	0	0	0	0
Total	8884	9788	11	19	16	16	463	2	3	1	3

[a] B, boys, G, girls.

Table 3. Prevalence of positive ATG (anti-thyroglobulin antibody) and AMC (anti-microsome antibody) titers by sex and place of residence.[a]

Place of residence	Number of subjects measured			Antibody					
				Anti-thyroglobulin			Anti-microsome		
	Total	Boys	Girls	Total	Boys	Girls	Total	Boys	Girls
Vishgorodskii	2600	1281	1319	25 (1.0)	8 (0.6)	17 (1.3)	56 (2.2)	16 (1.2)	40 (3.0)
Polesskii	795	396	399	2 (0.3)	2 (0.5)	0	6 (0.8)	3 (0.8)	3 (0.8)
Borodyanskii	1940	942	998	23 (1.2)	2 (0.2)	21 (2.1)	37 (1.9)	7 (0.7)	30 (3.0)
Makarovskii	905	411	494	8 (0.9)	4 (1.0)	4 (0.8)	6 (0.7)	1 (0.2)	5 (1.0)
Ivankovskii	1250	631	619	15 (1.2)	2 (0.3)	13 (2.1)	22 (1.8)	5 (0.8)	17 (2.7)
Kiev City	675	306	369	15 (2.2)	3 (1.0)	12 (3.3)	27 (4.0)	7 (2.3)	20 (5.4)
Irpenskii	2002	923	1079	37 (1.8)	6 (0.7)	31 (2.9)	40 (2.0)	8 (0.9)	32 (3.0)
Vasilkovskii	569	267	302	1 (0.2)	0	1 (0.3)	0	0	0
Baryshevskii	230	130	100	5 (2.2)	0	5 (5.0)	9 (3.9)	3 (2.3)	6 (6.0)
Svyatoshinskii	1549	746	803	18 (1.2)	5 (0.7)	13 (1.6)	36 (2.3)	10 (1.3)	26 (3.2)
Kagarlytskii	787	345	442	6 (0.8)	0	6 (1.4)	15 (1.9)	3 (0.9)	12 (2.7)
Fastovskii	599	220	379	7 (1.2)	2 (0.9)	5 (1.3)	23 (3.8)	8 (3.6)	15 (4.0)
Belotserkovskii	415	202	213	4 (1.0)	1 (0.5)	3 (1.4)	6 (1.4)	1 (0.5)	5 (2.3)
Brovarskii	1490	723	767	15 (1.0)	5 (0.7)	10 (1.3)	30 (2.0)	7 (1.0)	23 (3.0)
Borispolskii	297	156	141	3 (1.0)	0	3 (2.1)	6 (2.0)	1 (0.6)	5 (3.5)
Boguslavskii	8	3	5	0	0	0	0	0	0
Obukhovskii	665	341	324	5 (0.8)	1 (0.3)	4 (1.2)	10 (1.5)	2 (0.6)	8 (2.5)
Rakitnyanskii	1060	478	582	19 (1.8)	5 (1.0)	14 (2.4)	41 (3.9)	16 (3.3)	25 (4.3)
Stavischenskii	782	362	420	16 (2.0)	5 (1.4)	11 (2.6)	27 (3.5)	6 (1.7)	21 (5.0)
Taraschanskii	7	3	4	1 (14.3)	0	1 (25.0)	1 (14.3)	0	1 (25.0)
Volodarskii	1	0	1	0	0	0	0	0	0
Mironovskii	23	9	14	0	0	0	1 (4.3)	1 (11.1)	0
Skvirskii	10	4	6	0	0	0	0	0	0
Tetievskii	3	2	1	0	0	0	0	0	0
Yagotinskii	10	3	7	0	0	0	0	0	0
P-Khmelnitskii	12	6	6	1 (8.3)	1 (16.7)	0	0	0	0
Total	18 684	8890	9794	226 (1.2)	52 (0.6)	174 (1.8)	399 (2.1)	105 (1.2)	294 (3.0)

[a] Number of subjects with percentages in parentheses.

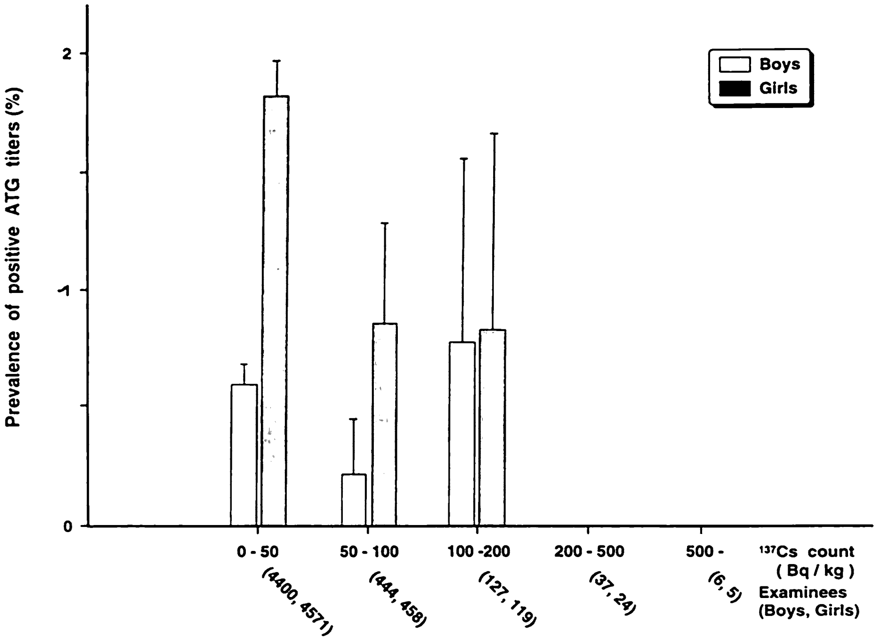

Figure 11. Prevalence of positive ATG titers by sex and whole body ^{137}Cs count per kg body weight. The whiskers denote the standard errors.

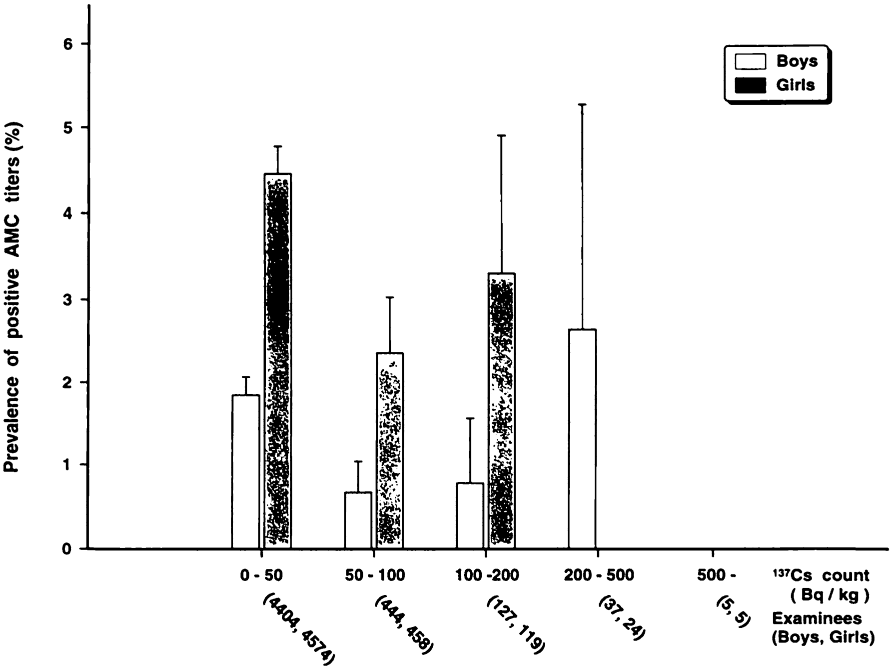

Figure 12. Prevalence of positive AMC titers by sex and whole body ^{137}Cs count per kg body weight. The whiskers denote the standard errors.

Based on the analysis of the investigation of thyroid hormone level (TSH and FT_4), the number of children with hypothyroidism and hyperthyroidism was 7 and 16, respectively. There were 11 girls among them (Table 4). All children underwent a course of appropriate treatment.

Since 1989, 27 children with thyroid cancer have been found by the Regional Endocrinology Dispensary staff in Kiev Oblast. Childhood thyroid cancer was not registered from 1986 to 1989. Four cases of thyroid cancer were discovered by the "Sasakawa-Chernobyl" Diagnostic Center team in the course of the screening examination. Among these there were 3 girls and 1 boy, and 3 cases were preoperatively diagnosed with echo-guided fine needle aspiration biopsy and cytological diagnosis. The histological findings of operated thyroid cancer showed 3 cases of papillary carcinoma and 1 case of the follicular variant of papillary carcinoma.

Table 4. Number of subjects with hypothyroidism and hyperthyroidism by sex and place of residence.

Place of residence	Number of subjects with measurment			Hypothyroidism[a]			Hyperthyroidism[b]		
	Total	Boys	Girls	Total	Boys	Girls	Total	Boys	Girls
Vishgorodskii	2583	1276	1307	0	0	0	1	1	0
Polesskii	795	396	399	0	0	0	0	0	0
Borodyanskii	1935	940	995	2	0	2	1	0	1
Makarovskii	905	411	494	0	0	0	0	0	0
Ivankovskii	1251	631	620	0	0	0	0	0	0
Kiev City	675	306	369	0	0	0	3	1	2
Irpenskii	2001	925	1076	1	1	0	2	0	2
Vasilkovskii	568	267	301	0	0	0	0	0	0
Baryshevskii	230	130	100	0	0	0	0	0	0
Svyatoshinskii	1549	746	803	1	0	1	2	0	2
Kagarlytskii	786	345	441	0	0	0	3	1	2
Fastovskii	598	220	378	1	1	0	1	0	1
Belotserkovskii	415	202	213	0	0	0	1	0	1
Brovarskii	1485	720	765	1	1	0	2	2	0
Borispolskii	297	156	141	0	0	0	0	0	0
Boguslavskii	8	3	5	0	0	0	0	0	0
Obukhovskii	665	341	324	0	0	0	0	0	0
Rakitnyanskii	1060	478	582	1	0	1	0	0	0
Stavischenskii	777	358	419	0	0	0	0	0	0
Taraschanskii	7	3	4	0	0	0	0	0	0
Volodarskii	1	0	1	0	0	0	0	0	0
Mironovskii	23	9	14	0	0	0	0	0	0
Skvirskii	10	4	6	0	0	0	0	0	
Tetievskii	3	2	1	0	0	0	0	0	0
Yagotinskii	9	3	6	0	0	0	0	0	0
P-Khmelnitskii	11	5	6	0	0	0	0	0	0
Total	18 647	8877	9770	7	3	4	16	5	11

[a] Diagnosed when free $T_4 < 10.0$ pmol/L and TSH > 2.90 μIU/mL.

[b] Diagnosed when free $T_4 > 25.0$ pmol/L and TSH < 0.24 μIU/mL.

3.4 Hematological studies

Figure 13 shows the relationship between Hb level and sex and age. The trend towards an increase in the Hb level with age in both boys and girls is still found. In the age group from 13 to 17 the increase in Hb level was more pronounced in boys than in girls of the same age. Of the 45 children showing a reduction in Hb level below 110 g/L, 43 had iron deficiency anemia and 2 girls revealed post-hemorrhagic anemia. The Hb level returned to the normal range after a course of treatment with ferrous-containing drugs.

Figure 14 shows the relationship between MCV level and sex and age. An increase in MCV level with age was observed in both boys and girls. The median of MCV was within normal range but in a group of boys the MCV level was lower than that in girls in all age groups. A sharp reduction in MCV (< 70 fl) was observed in 30 boys and 12 girls. The analysis of data on Hb level in these children showed that a reduction below 110 g/L was registered in only 6 boys and 10 girls. In all remaining cases the Hb level was within the normal limits. A total of 19 girls and 11 boys showed an increase exceeding the upper limit of the MCV range.

The number of platelets (PLT) was within the normal limits in most of the children examined (Figure 15). A decrease in PLT count below $100 \times 10^9/L$ was found in 5 boys and 9 girls. Of these, 1 boy suffered from thrombocytopenic purpura of undetermined cause and 3 children showed Werlhof's disease for the first time. In all other cases the thrombocytopenia was without obvious clinical manifestations. A PLT count higher than $400 \times 10^9/L$ was noted in 163 boys and 161 girls. The PLT count showed a trend towards a reduction with age.

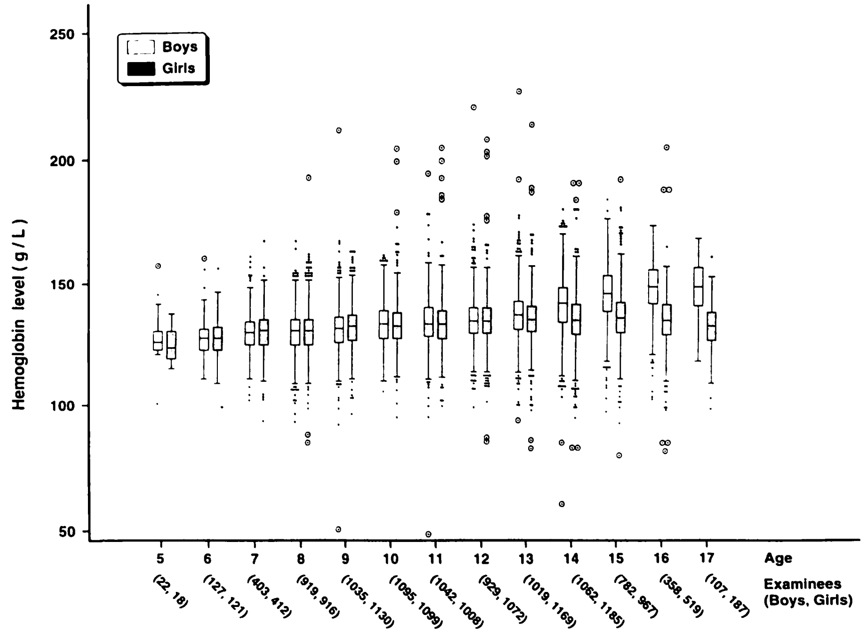

Figure 13. The box-and-whisker plots of hemoglobin level by sex and age. See Figure 2 for details.

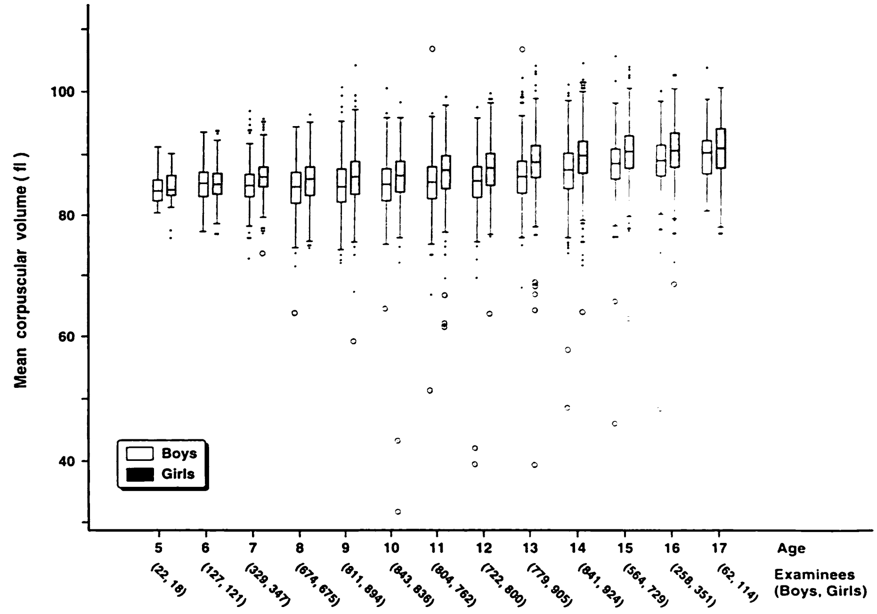

Figure 14. The box-and-whisker plots of mean corpuscular volume by sex and age. See Figure 2 for details.

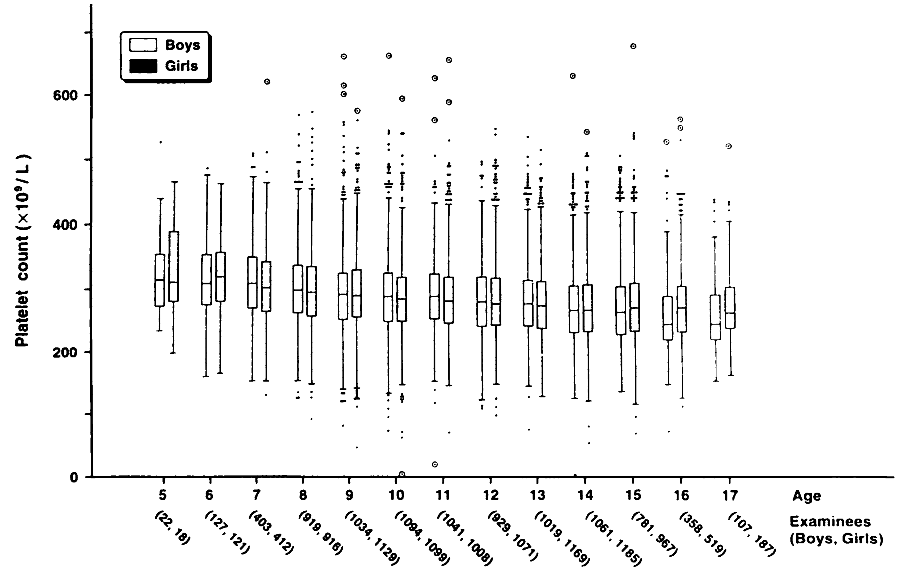

Figure 15. The box-and-whisker plots of platelet count by sex and age. See Figure 2 for details.

Figure 16 shows that the WBC count in most of the children was within normal range relative to sex. An increase in WBC higher than 11 × 10^9/L was found in 401 boys and 462 girls. No relationship between WBC count and place of residence was found. An increase in WBC count occurred most commonly in the group of children from 8 to 14 years old. Children from this group had chronic gastrointestinal, lung and rhynopharyngeal disorders. A decrease in WBC level below 3 × 10^9/L was noted in 11 girls and 10 boys. A further examination of the children over period of one month showed that the WBC level returned to the normal range.

A total of 1,365 children (7.3%) showed an increase in neutrophil count. The largest number of deviations in the neutrophil count was found in the group of children aged 5. Girls aged 13–16 showed a marked increase in neutrophil count.

A considerable number of deviations was noted in lymphocyte count. A total of 2,152 (11.5%) children were found to have an increase above normal limits, and this was more pronounced in the group of children aged 6–9 years. A significant number of lymphocytosis cases was found in Ivankovskii (227), Borodyanskii (223) and Irpenskii (214) Rayons. An analysis of the data revealed that the children suffered from chronic focal infectious diseases.

Tables 5A and 5B represent the frequency of hematological deviations from the normal range in boys and girls relative to place of residence. A high level was noted in eosinophil (14.1%) and lymphocyte (11.8%) counts. A decrease in MCV was registered in 5% of the cases. An elevated WBC count was noted in 4.6%, and a decrease in WBC count was observed in 0.4%.

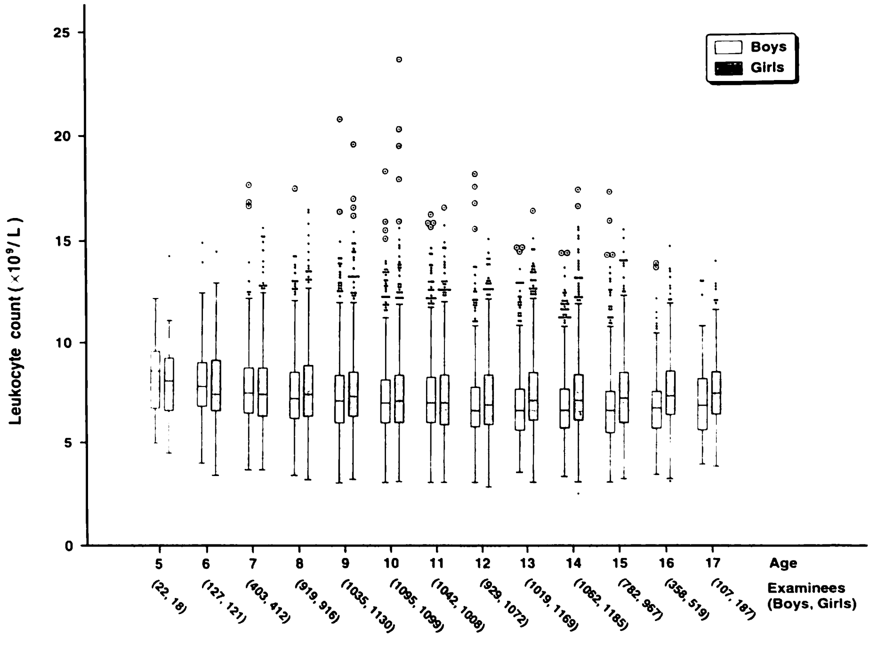

Figure 16. The box-and-whisker plots of leukocyte count by sex and age. See Figure 2 for details.

Table 5A. Frequency of boys with

Blood analysis		Place of										
Item (unit)[c]	Abnormality criteria	VIS	POL	BOR	MAK	IVN	KIE	IRP	VAS	BSH	SVY	KAG
Hb (g/L)	< 110	2 (0.2)	2 (0.5)	3 (0.3)		4 (0.6)	2 (0.7)	1 (0.1)	1 (0.4)		12 (1.6)	1 (0.3)
	> 180	1 (0.1)		3 (0.3)					1 (0.4)		1 (0.1)	
WBC (×10⁹/L)	< 3.8	11 (0.9)	1 (0.3)	1 (0.1)		2 (0.3)	5 (1.6)	3 (0.3)			4 (0.5)	3 (0.9)
	> 10.6	34 (2.7)	37 (9.3)	66 (7.0)	21 (5.1)	30 (4.8)	15 (4.9)	40 (4.3)	16 (6.0)	6 (4.7)	16 (2.1)	23 (6.6)
PLT (×10⁹/L)	< 100			1 (0.1)	1 (0.2)							1 (0.3)
	> 440	20 (1.6)	10 (2.5)	17 (1.8)	11 (2.7)	11 (1.8)	7 (2.3)	9 (1.0)	9 (3.4)	1 (0.8)	10 (1.3)	5 (1.4)
MCV (fl)	< 80	156 (12.2)	16 (4.0)	138 (14.7)	20 (4.9)	20 (3.2)	22 (7.2)	100 (10.8)	4 (1.5)		37 (5.0)	
	> 100			2 (0.2)		1 (0.2)					1 (0.1)	
Ly (×10⁹/L)	< 1.2	19 (1.5)	4 (1.0)	19 (2.0)	12 (2.9)	15 (2.4)	11 (3.6)	22 (2.4)	2 (0.8)		39 (5.2)	8 (2.3)
	> 3.5	91 (7.1)	83 (21.0)	99 (10.5)	62 (15.1)	118 (18.9)	30 (9.8)	89 (9.6)	13 (4.9)	21 (16.5)	57 (7.7)	85 (24.6)
Ne (×10⁹/L)	< 1.4	40 (3.1)	2 (0.5)	1 (0.1)	1 (0.2)	1 (0.2)	5 (1.6)	6 (0.6)			12 (1.6)	2 (0.6)
	> 6.6	39 (3.0)	25 (6.3)	69 (7.3)	25 (6.1)	32 (5.1)	17 (5.5)	54 (5.8)	22 (8.3)	9 (7.1)	26 (3.5)	28 (8.1)
Eo (×10⁹/L)	> 0.5	182 (14.2)	105 (26.5)	169 (18.0)	109 (26.5)	104 (16.6)	31 (10.1)	88 (9.5)	50 (18.9)	21 (16.5)	48 (6.4)	65 (18.8)
Mo (×10⁹/L)	< 0.12	45 (3.5)	58 (14.6)	71 (7.6)	30 (7.3)	110 (17.6)	13 (4.2)	32 (3.4)	1 (0.4)	14 (11.0)	56 (7.5)	46 (13.3)
	> 1.00	30 (2.3)	12 (3.0)	12 (1.3)	12 (2.9)	5 (0.8)	6 (2.0)	7 (0.8)	2 (0.8)	3 (2.4)	10 (1.3)	2 (0.6)
Number of children measured		1280	396	940	411	625	307	928	265	127	745	346

[a] Parenthetic entries refer to the percentage of the subjects while empty spaces denote the absence of subjects

[b] VIS, Vishgorodskii; POL, Polesskii; BOR, Borodyanskii; MAK, Makarovskii; IVN, Ivankovskii; KIE, FAS, Fastovskii; BEL, Belotserkovskii; BRO, Brovarskii; BRP, Borispolskii; BOG, Boguslavskii; OBU, Skvirskii; TET, Tetievskii; YAG, Yagotinskii.

[c] Hb, hemoglobin; WBC, white blood cell (leukocyte); PLT, platelet; MCV, mean corpuscular volume; Ly,

The largest number of deviations from the normal range was observed during eosinophil investigations. An increase in eosinophil count was found in 1,270 (14.3%) of the boys and 1,367 (13.9%) of the girls. The relationship between eosinophilia and skin diseases, asthma and the presence of domestic animals was investigated. A correlation was observed only between eosinophilia and the presence of domestic animals. The prevalence of eosinophilia was 27.5% in children with domestic animals but was only 14.6% in children without domestic animals. After a course of treatment with antihelminthic drugs, the eosinophil count decreased. The number of cases of hematological abnormalities by place of residence.[a]

residence[b]													Total
FAS	BEL	BRO	BRP	BOG	OBU	RAK	STV	TAR	MIR	SKV	TET	YAG	
2		5	2		5	1	1						44
(0.9)		(0.7)	(1.3)		(1.5)	(0.2)	(0.3)						(0.5)
					2	1							9
					(0.6)	(0.2)							(0.1)
2	2	5	2		14		1						57
(0.9)	(0.9)	(0.7)	(1.3)		(4.1)		(0.3)						(0.6)
19	6	15	5		11	29	10	1	1		1		401
(8.3)	(2.8)	(2.1)	(3.2)		(3.2)	(6.1)	(2.8)	(33.3)	(12.5)		(50.0)		(4.5)
						2							5
						(0.4)							(0.1)
	4	13	6		18	7	4			1			163
	(1.9)	(1.8)	(3.8)		(5.3)	(1.5)	(1.1)			(25.0)			(1.8)
1	7	77			3	12	4		1				618
(0.4)	(3.3)	(10.7)			(0.9)	(2.5)	(1.1)		(12.5)				(6.9)
2	2					2	1						11
(0.9)	(0.9)					(0.4)	(0.3)						(0.1)
9	8	12	7		50	25	36	1	2		1		302
(3.9)	(3.7)	(1.7)	(4.5)		(14.7)	(5.2)	(10.0)	(33.3)	(25.0)		(50.0)		(3.4)
43	23	31	13	1	27	62	43	1	1			1	994
(18.7)	(10.7)	(4.3)	(8.3)	(33.3)	(7.9)	(13.0)	(11.9)	(33.3)	(12.5)			(33.3)	(11.2)
1	5	6	1		7	4							94
(0.4)	(2.3)	(0.8)	(0.6)		(2.1)	(0.8)							(1.1)
18	11	16	7		18	41	32	1		2	1		493
(7.8)	(5.1)	(2.2)	(4.5)		(5.3)	(8.6)	(8.9)	(33.3)		(50.0)	(50.0)		(5.5)
32	13	85	20		23	64	55	1	3	1		1	1270
(13.9)	(6.0)	(11.8)	(12.8)		(6.8)	(13.4)	(15.2)	(33.3)	(37.5)	(25.0)		(33.3)	(14.3)
26	15	12	11		44	53	43		1			1	682
(11.3)	(7.0)	(1.7)	(7.1)		(12.9)	(11.1)	(11.9)		(12.5)			(33.3)	(7.7)
2	1	3			5	5	3						120
(0.9)	(0.5)	(0.4)			(1.5)	(1.0)	(0.8)						(1.3)
230	215	722	156	3	340	478	361	3	8	4	2	3	8895

with abnormalities.

Kiev City; IRP, Irpenskii; VAS, Vasilkovskii; BSH, Baryshevskii; SVY, Svyatoshinskii; KAG, Kagarlytskii; Obukhovskii; RAK, Rakitnyanskii; STV, Stavischenskii; TAR, Taraschanskii; MIR, Mironovskii; SKV,

lymphocyte; Ne, neutrophil; Eo, eosinophil; Mo, monocyte.

eosinophilia was 16.1% (1,008 of 6,248 children) in the autumn and 10.8% (610 of 5,661 children) in the spring.

We studied the correlation of ferritin level with Hb level, MCV count, age and sex. A total of 86 children with Hb < 110 g/L and 142 children with MCV < 80 fl were examined. The results are presented in Figures 17–19. Figures 18 and 19 show the correlation of ferritin level by Hb and MCV. The respective correlation coefficients were 0.2 and 0.1, both of which are not statistically significant ($p > 0.05$). We also studied the relationship of ferritin level with soil ^{137}Cs contamination level, but no

Table 5B. Frequency of girls with

Blood analysis												Place of
Item (unit)[c]	Abnormality criteria	VIS	POL	BOR	MAK	IVN	KIE	IRP	VAS	BSH	SVY	KAG
Hb (g/L)	< 110	1	1	5	3	2	5	3	2		21	4
		(0.1)	(0.3)	(0.5)	(0.6)	(0.3)	(1.4)	(0.3)	(0.7)		(2.6)	(0.9)
	> 160	10	1	12	1	5	3	2	2	3	15	1
		(0.8)	(0.3)	(1.2)	(0.2)	(0.8)	(0.8)	(0.2)	(0.7)	(3.0)	(1.9)	(0.2)
WBC (×10⁹/L)	< 3.6	4				1	3	1			3	1
		(0.3)				(0.2)	(0.8)	(0.1)			(0.4)	(0.2)
	> 11.0	58	32	75	15	36	9	34	34	9	24	29
		(4.4)	(8.0)	(7.5)	(3.0)	(5.9)	(2.5)	(3.1)	(11.2)	(9.0)	(3.0)	(6.6)
PLT (×10⁹/L)	< 100	2			1			1			1	
		(0.2)			(0.2)			(0.1)			(0.1)	
	> 440	26	10	12	5	7	8	7	9	4	13	6
		(2.0)	(2.5)	(1.2)	(1.0)	(1.1)	(2.2)	(0.6)	(3.0)	(4.0)	(1.6)	(1.4)
MCV (fl)	< 80	84	6	61	7	10	15	45	3		17	2
		(6.4)	(1.5)	(6.1)	(1.4)	(1.6)	(4.1)	(4.2)	(1.0)		(2.1)	(0.5)
	> 100	1		1				1	2		1	
		(0.1)		(0.1)				(0.1)	(0.7)		(0.1)	
Ly (×10⁹/L)	< 1.2	33	2	27	10	23	15	11	1	4	72	18
		(2.5)	(0.5)	(2.7)	(2.0)	(3.8)	(4.1)	(1.0)	(0.3)	(4.0)	(9.0)	(4.1)
	> 3.5	118	86	124	76	109	42	125	21	14	56	102
		(9.0)	(21.5)	(12.4)	(15.4)	(17.8)	(11.4)	(11.6)	(6.9)	(14.0)	(7.0)	(23.1)
Ne (×10⁹/L)	< 1.4	22		3	4	2	12	5			9	1
		(1.7)		(0.3)	(0.8)	(0.3)	(3.3)	(0.5)			(1.1)	(0.2)
	> 6.6	104	28	139	30	55	16	61	57	16	57	47
		(7.9)	(7.0)	(13.9)	(6.1)	(9.0)	(4.4)	(5.6)	(18.8)	(16.0)	(7.1)	(10.6)
Eo (×10⁹/L)	> 0.5	183	79	171	122	122	34	118	34	23	50	76
		(13.9)	(19.8)	(17.1)	(24.6)	(20.0)	(9.3)	(10.9)	(11.2)	(23.0)	(6.3)	(17.2)
Mo (×10⁹/L)	< 0.12	63	63	90	37	101	18	42	3	10	63	61
		(4.8)	(15.8)	(9.0)	(7.5)	(16.5)	(4.9)	(3.9)	(1.0)	(10.0)	(7.9)	(13.8)
	> 1.00	23	11	9	11	7	2	5			5	2
		(1.8)	(2.8)	(0.9)	(2.2)	(1.1)	(0.5)	(0.5)			(0.6)	(0.5)
Number of children measured		1312	400	1001	495	611	367	1081	304	100	798	442

[a] Parenthetic entries refer to the percentage of the subjects while empty spaces denote the absence of subjects

[b] VIS, Vishgorodskii; POL, Polesskii; BOR, Borodyanskii; MAK, Makarovskii; IVN, Ivankovskii; KIE, FAS, Fastovskii; BEL, Belotserkovskii; BRO, Brovarskii; BRP, Borispolskii; BOG, Boguslavskii; OBU, Mironovskii; SKV, Skvirskii; TET, Tetievskii; YAG, Yagotinskii; PKH, P-Khmelnitskii.

[c] Hb, hemoglobin; WBC, white blood cell (leukocyte); PLT, platelet; MCV, mean corpuscular volume; Ly,

correlation was observed.

Table 6 presents the results of repeated investigations. Of the 64 children with lymphocytosis re-examined, 23 once again showed a high lymphocyte count without obvious signs. Out of the 18 children with anemia, 10 had a normal Hb level after a course of treatment and 8 still had a Hb level < 110 g/L. Out of 86 children with eosinophilia, 24 were found to have a high eosinophil count after a course of desensitizing and anthelminthic therapy. These children require further observation. We re-examined 12 children with thrombocytopenia, and PLT count remained low hematological abnormalities by place of residence.[a]

residence[b]

FAS	BEL	BRO	BRP	BOG	OBU	RAK	STV	TAR	ZGU	MIR	SKV	TET	YAG	PKH	Total
2		6	2		7	2				1					67
(0.5)		(0.8)	(1.4)		(2.2)	(0.3)				(7.1)					(0.7)
1	3	1	2		14	6	4			3					89
(0.3)	(1.4)	(0.1)	(1.4)		(4.3)	(1.0)	(0.9)			(21.4)					(0.9)
	1		1		9	1	2								27
	(0.5)		(0.7)		(2.8)	(0.2)	(0.5)								(0.3)
19	11	15	7		7	29	17			1			1		462
(4.8)	(5.0)	(2.0)	(5.0)		(2.2)	(5.0)	(4.0)			(7.1)			(14.3)		(4.7)
		1				2	1								9
		(0.1)				(0.3)	(0.2)								(0.1)
	2	12	5		24	3	5			2			1		161
	(0.9)	(1.6)	(3.5)		(7.4)	(0.5)	(1.2)			(14.3)			(14.3)		(1.6)
3	6	46		1	2	7	3							1	319
(0.8)	(2.7)	(6.0)		(20.0)	(0.6)	(1.2)	(0.7)							(16.7)	(3.3)
3						6	3							1	19
(0.8)						(1.0)	(0.7)							(16.7)	(0.2)
15	8	16	13	1	47	40	33			2	1			1	393
(3.8)	(3.6)	(2.1)	(9.2)	(20.0)	(14.5)	(6.9)	(7.8)			(14.3)	(16.7)			(16.7)	(4.0)
54	40	38	10		26	65	48			1			1		1156
(13.7)	(18.2)	(5.0)	(7.1)		(8.0)	(11.2)	(11.3)			(7.1)			(14.3)		(11.8)
1	2	3	1		6	4	1								76
(0.3)	(0.9)	(0.4)	(0.7)		(1.9)	(0.7)	(0.2)								(0.8)
47	16	34	8	1	30	66	51			2	2	1	2	2	872
(11.9)	(7.3)	(4.5)	(5.7)	(20.0)	(9.3)	(11.3)	(12.0)			(14.3)	(33.3)	(100.0)	(28.6)	(33.3)	(8.9)
52	22	111	14		27	72	54	1	1				1		1367
(13.2)	(10.0)	(14.5)	(9.9)		(8.3)	(12.4)	(12.7)	(25.0)	(100.0)				(14.3)		(13.9)
54	13	18	16		36	66	65				2			1	882
(13.7)	(5.9)	(2.4)	(11.3)		(11.1)	(11.3)	(15.3)				(33.3)			(16.7)	(8.4)
2	1	8	2		1	8	2								99
(0.5)	(0.5)	(1.0)	(1.4)		(0.3)	(1.4)	(0.5)								(1.0)
394	220	764	141	5	324	582	425	4	1	14	6	1	7	6	9805

with abnormalities.

Kiev City; IRP, Irpenskii; VAS, Vasilkovskii; BSH, Baryshevskii; SVY, Svyatoshinskii; KAG, Kagarlytskii; Obukhovskii; RAK, Rakitnyanskii; STV, Stavischenskii; TAR, Taraschanskii; ZGU, Zgurovskii; MIR,

lymphocyte; Ne, neutrophil; Eo, eosinophil; Mo, monocyte.

(< 100 × 10^9/L). Only three were found to be Werlhof's disease; no cause was found in the other cases.

Tables 7A and 7B show the correlation of the hematological deviations from the normal limits by ^{137}Cs content level in the body. The majority of the examined children showed a ^{137}Cs concentration level in the range of 0–50 Bq/kg, which means that a major portion of deviations was within the above range.

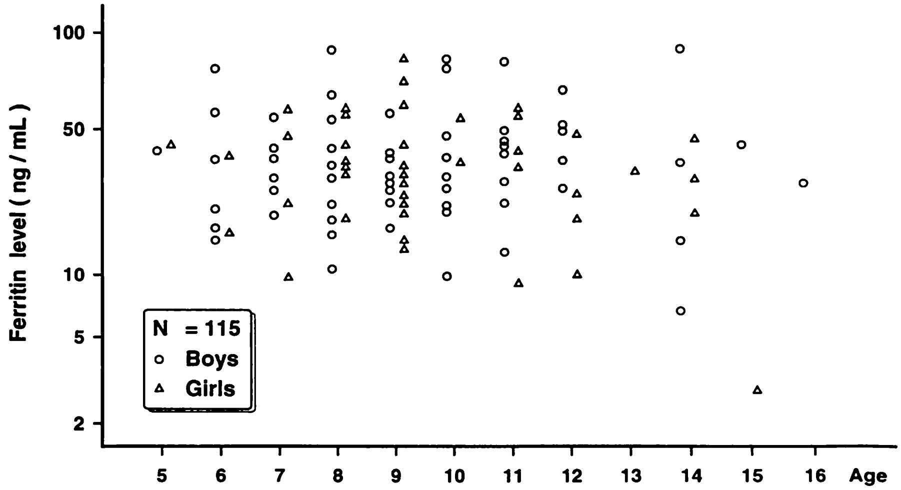

Figure 17. Distribution of ferritin level by age and sex in hematologically normal children.

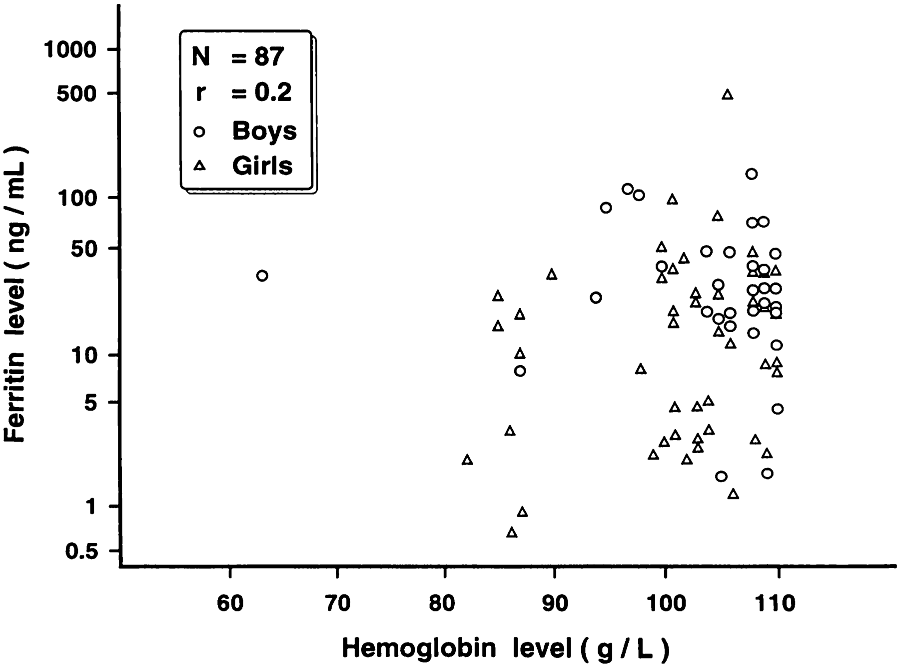

Figure 18. Scatter plots of hemoglobin (Hb) and ferritin levels in children with Hb less than 110 g/L.

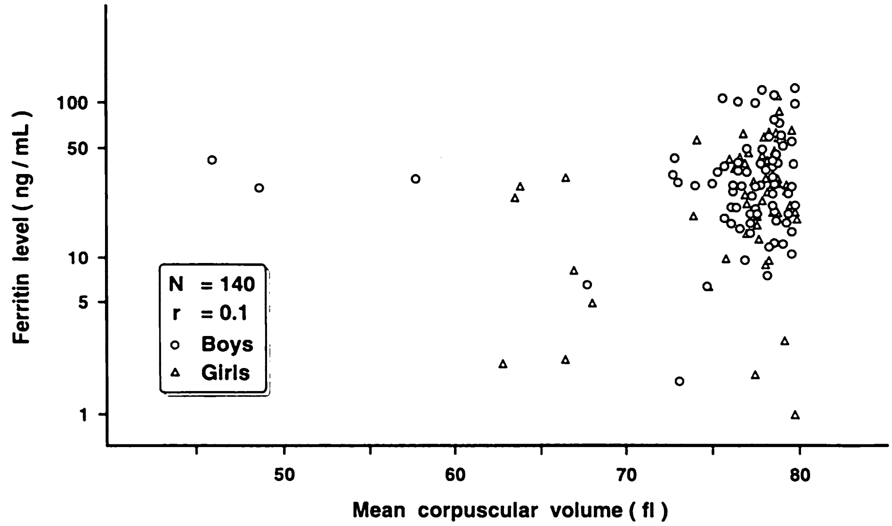

Figure 19. Scatter plots of mean corpuscular volume (MCV) and ferritin levels in children with MCV less than 80 fl.

Table 6. Results of re-examination of children found to have hematological abnormalities at the screening.

Blood analysis		Number of children with abnormalities at screening	Number of children undergoing re-examination	Results of re-examination
Item (unit)[a]	Abnormality criteria			
Hb (g/L)	< 110	111	18	10 - normal 8 - iron deficiency anemia
WBC ($\times 10^9$/L)	< 3.8 for boys < 3.6 for girls	84	12	10 - normal 2 - leukopenia
PLT ($\times 10^9$/L)	< 100	14	12	3 - Werlhof's disease 9 - thrombocytopenia, etiology unknown
Ly ($\times 10^9$/L)	> 3.5	2152	64	41 - normal 23 - lymphocytosis
Eo ($\times 10^9$/L)	> 0.5	2638	86	62 - normal 24 - eosinophilia
Mo ($\times 10^9$/L)	> 1.0	219	9	6 - normal 3 - monocytosis

[a] Hb, hemoglobin; WBC, white blood cell (leukocyte); PLT, platelet; Ly, lymphocyte; Eo, eosinophil; Mo, monocyte.

Table 7A. Frequency of boys with hematological abnormalities by ^{137}Cs level.[a]

Blood analysis		Whole body ^{137}Cs count per body weight (Bq/kg)					Total
Item (unit)[b]	Abnormality criteria	0–50	50–100	100–200	200–500	500–	
Hb (g/L)	< 110	41 (0.5)	3 (0.7)				44 (0.5)
	> 180	9 (0.1)					9 (0.1)
WBC ($\times 10^9$/L)	< 3.8	55 (0.7)	1 (0.2)	1 (0.8)			57 (0.6)
	> 10.6	268 (4.4)	19 (4.3)	10 (8.0)	4 (10.8)		401 (4.5)
PLT ($\times 10^9$/L)	< 100	5 (0.1)					5 (0.1)
	> 440	153 (1.8)	8 (1.8)		2 (5.4)		163 (1.8)
MCV (fl)	< 80	583 (7.0)	28 (6.3)	6 (4.8)	1 (2.7)		618 (6.9)
	> 100	11 (0.1)					11 (0.1)
Ly ($\times 10^9$/L)	< 1.2	294 (3.5)	7 (1.6)	1 (0.8)			302 (3.4)
	> 3.5	892 (10.8)	74 (16.6)	23 (18.4)	5 (13.5)	1 (16.7)	995 (11.2)
Ne ($\times 10^9$/L)	< 1.4	92 (1.1)		2 (1.6)			94 (1.1)
	> 6.6	465 (5.6)	19 (4.3)	7 (5.6)	2 (5.4)		493 (5.5)
Eo ($\times 10^9$/L)	> 0.5	1147 (13.8)	87 (19.6)	27 (21.6)	9 (24.3)	1 (16.7)	1271 (14.3)
Mo ($\times 10^9$/L)	< 0.12	601 (7.3)	49 (11.0)	23 (18.4)	9 (24.3)		682 (7.7)
	> 1.00	96 (1.2)	14 (3.1)	6 (4.8)	3 (8.1)	1 (16.7)	120 (1.3)
Number of children measured		8289	445	125	37	6	8902

[a] Parenthetic entries refer to the percentage of the subjects while empty spaces denote the absence of subjects with abnormalities.

[b] Hb, hemoglobin; WBC, white blood cell (leukocyte); PLT, platelet; MCV, mean corpuscular volume; Ly, lymphocyte; Ne, neutrophil; Eo, eosinophil; Mo, monocyte.

Table 7B. Frequency of girls with hematological abnormalities by ^{137}Cs level.[a]

Blood analysis		Whole body ^{137}Cs count per body weight (Bq/kg)					Total
Item (unit)[b]	Abnormality criteria	0–50	50–100	100–200	200–500	500–	
Hb (g/L)	< 110	63 (0.7)	2 (0.4)		1 (4.3)	1 (20.0)	67 (0.7)
	> 160	85 (0.9)	1 (0.2)	3 (2.5)			89 (0.9)
WBC ($\times 10^9$/L)	< 3.6	25 (0.3)	2 (0.4)				27 (0.3)
	> 11.0	429 (4.7)	24 (5.2)	7 (5.9)	2 (8.7)		462 (4.7)
PLT ($\times 10^9$/L)	< 100	8 (0.1)	1 (0.2)				9 (0.1)
	> 440	151 (1.6)	8 (1.7)	2 (1.7)			161 (1.6)
MCV (fl)	< 80	306 (3.3)	12 (2.6)	1 (0.8)			319 (3.3)
	> 100	19 (0.2)					19 (0.2)
Ly ($\times 10^9$/L)	< 1.2	378 (4.1)	13 (2.8)	1 (0.8)	1 (4.3)		393 (4.0)
	> 3.5	1156 (11.5)	78 (16.9)	17 (14.3)	2 (8.7)		1156 (11.8)
Ne ($\times 10^9$/L)	< 1.4	73 (0.8)	2 (0.4)		1 (4.3)		76 (0.8)
	> 6.6	832 (9.0)	29 (6.3)	8 (6.7)	3 (13.0)		872 (8.9)
Eo ($\times 10^9$/L)	> 0.5	1265 (13.8)	81 (17.5)	17 (14.3)	3 (13.0)	1 (20.0)	1367 (13.9)
Mo ($\times 10^9$/L)	< 0.12	731 (7.9)	71 (15.4)	15 (12.6)	4 (17.4)	1 (20.0)	822 (8.4)
	> 1.00	85 (0.9)	9 (1.9)	5 (4.2)			99 (1.0)
Number of children measured		9197	462	119	23	5	9806

[a] Parenthetic entries refer to the percentage of the subjects while empty spaces denote the absence of subjects with abnormalities.

[b] Hb, hemoglobin; WBC, white blood cell (leukocyte); PLT, platelet; MCV, mean corpuscular volume; Ly, lymphocyte; Ne, neutrophil; Eo, eosinophil; Mo, monocyte.

4. Conclusions

Nine years have passed since the Chernobyl accident but so far no relationship has been established between the thyroid abnormalities and ^{137}Cs accumulation level in the body.

Thyroid cancers were found not only in children exposed to high doses (200 cGy) but also in those with lower doses (up to 50 cGy).

Girls revealed thyroid abnormalities more frequently than boys.

The higher sensitivity of the thyroid to radiation implies various factors such as unfavorable environmental situation, iodine deficit in the biosphere and psychoemotional state. Iodine deficiency provokes an increase in thyroid abnormalities including cancer. However, the iodine deficiency is not the only reason for cancer. An iodine deficiency was registered before the Chernobyl catastrophe, particularly in the northern rayons, but thyroid cancers were not observed there.

Blood testing showed an increase in eosinophilia and lymphocytosis as well as in anemia among children. The number of children with atypical lymphocyte and monocyte morphology increased. These hematological abnormalities did not correlate either with the contamination level in their place of residence or with whole body ^{137}Cs count.

It is necessary to continue these investigations and to carefully observe the state of the thyroid in children, taking into consideration the dose burden from external and internal exposure as well as the iodine content in the biosphere and other environmental factors.

Results of the Examination of Children Residing in the Northern Rayons of Zhitomir Oblast

Korosten Inter-Area Medical Diagnostic Center

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1. Introduction

The investigation of the health status of children residing in the northern rayons (districts) of Zhitomir Oblast (Province) has been carried out in Korosten City over the four-year period from May 1991 to December 1994 using the Chernobyl Sasakawa mobile diagnostic laboratory and a set of stationary equipment in the diagnostic center.

The area is contaminated with radionuclides, contamination levels ranging from 1 to 40 Ci/km^2 and higher. The population of the territory is 500,000 people, including 84,000 children (Figure 1).

The course of the examination includes the following: (1) collection of disease history and filling in of questionnaires; (2) anthropometric data; (3) measurement of ^{137}Cs specific activity in the body; (4) ultrasonography of the thyroid; (5) peripheral blood ferritin assays; (6) determination of thyroid hormonal status and positive titers of antithyroid autoantibodies in serum; (7) measurement of urinary iodine and creatinine contents; (8) examination of children by an endocrinologist, hematologist and other specialists, if required; and (9) fine needle aspiration (FNA) biopsy and cytological diagnosis under the supervision of Japanese specialists.

The information thus obtained is processed and then entered into a database. If abnormalities are found, the child in question is invited to visit the center for a comprehensive examination, professional consultation and recommendations for appropriate treatment, and, if required, they are sent to regional or republican medical institutions.

2. Materials and Methods

2.1 Study subjects

The subjects under study are children from 5 to 15 years of age who were born in the period from 26 April 1976 to 26 April 1986.

2.2 Measurement of whole body ^{137}Cs concentration

The technique of direct spectrometry of radionuclide activity based on the registration of gamma radiation in the body was used. The spectrometry was carried out with the whole body counter Model-101 manufactured by Aloka Company (Japan).

2.3 Thyroid examinations

An ultrasonographic unit (arch-automatic scanning type, Aloka SSD-520) was used in this study. Eleven cross sections of the thyroid gland were obtained by the technique of automatic scanning at 5 mm intervals. The thyroid images were recorded and stored on optic disc.

The following criteria were used to establish a diagnosis for each child: thyroid structure; echogenity; thyroid volume; laboratory data (general blood count, thyroid function, urinary iodine content, positive titers of anti-thyroglobulin antibodies (ATG) and anti-microsome antibodies (AMC); physical data (height, weight and age) and the results of the functional examination (ECG).

The criterion for goiter is a thyroid volume exceeding the volume calculated by the following formula:

$$LIMIT = 1.7 \times 10^{0.013 \times age + 0.0028 \times height} \times (body\ weight)^{0.15},$$

where *age* is the age of a child in years at the time of the examination; *height* is the height of a child in cm; and *body weight* is the weight of a child in kg.

Free thyroxine (FT_4) and thyroid stimulating hormone (TSH) levels in blood serum were assayed with the Amerlite analyzer system using an immunometric method based on enhanced luminescence. Titers of ATG and AMC antibodies were assayed by the reaction of indirect hemagglutination (Fujirevio, Japan).

2.4 Hematological studies

Blood testing was conducted with a Sysmex K-1000 hemoanalyzer to determine the following eight parameters: (1) white blood cell count (WBC); (2) red blood cell count (RBC); (3) hemoglobin (Hb); (4) mean corpuscular volume (MCV); (5) hematocrit (Ht); (6) mean corpuscular hemoglobin (MCH); (7) mean corpuscular hemoglobin concentration (MCHC); and (8) platelet count (PLT). A Sysmex NE-7000 analyzer was also used to obtain the following 23 parameters: WBC; RBC; Hb; Ht; MCV; MCH; MCHC; PLT; three parameters of the quantitative status of platelets, i.e. platelet distribution width, mean platelet volume and platelet large cell ratio; neutrophil percent and neutrophil count; lymphocyte percent and lymphocyte count; monocyte percent and monocyte count; eosinophil percent and eosinophil count; basophil percent and basophil count; and two parameters of the quantitative status of RBC distribution width, i.e. coefficient of variation and standard deviation.

The staining of peripheral blood smears was performed by the May-Grünwald-Giemsa technique with the help of a "Sakura" device. Three smears (two stained and one fixed) were made for each examined child. The hemogram was analyzed with a BH-2 "Olympus" microscope.

3. Results

3.1 Study subjects

A total of 21,093 children were examined during the four-year period, but 2,301 children were excluded from the program due to their age parameters or re-examination.

Table 1 shows the classification of the examined children by age and place of residence. A total of 18,792 children (8,691 boys and 10,101 girls) residing in 11 rayons of Zhitomir Oblast were analyzed. The largest proportion of the examined children (5,660) live in Korostenskii Rayon, followed by Volodar-Volinskii (2,820) and Olevskii (1,546) Rayons.

Figure 1 shows ^{137}Cs contamination levels in the northern rayons of Zhitomir Oblast. The most contaminated rayons are Narodichskii, Ovruchskii, Korostenskii Rayons and Korosten City.

3.2 Measurement of whole body ^{137}Cs concentration

Figure 2 shows whole body ^{137}Cs count per kg body weight (Bq/kg) by sex and age

Table 1. Classification of study subjects by sex and place of residence.[a]

Place of residence	Boys	Girls	Total
Koroston City	1483 (8, 11, 13)	1678 (9, 11, 13)	3161 (9, 11, 13)
Korostenskii	2729 (9, 12, 14)	2931 (9, 12, 14)	5660 (9, 12, 14)
Luginskii	603 (9, 11, 13)	678 (9, 11, 14)	1281 (9, 11, 13)
Olevskii	679 (9, 12, 14)	867 (10, 12, 14)	1546 (10, 12, 14)
Malinskii	406 (8, 10, 12)	474 (8, 10, 12)	880 (8, 10, 12)
Emilchinskii	476 (9, 10, 12)	638 (9, 11, 13)	1114 (9, 10, 12)
Ovruchskii	347 (9, 11, 13)	517 (9, 12, 13)	864 (9, 11, 13)
Narodichskii	298 (10, 12, 14)	410 (10, 12, 14)	708 (10, 12, 14)
Novograd-Volinskii	207 (8, 10, 12)	267 (9, 11, 13)	474 (9, 11, 13)
Volodar-Volinskii	1321 (9, 11, 13)	1499 (10, 12, 14)	2820 (9, 12, 14)
Brusilovskii	129 (9, 11, 12)	123 (8, 10, 12)	252 (8, 11, 13)
Radomishliskii	13 (5, 6, 6)	19 (6, 6, 6)	32 (6, 6, 6)
Total	8691 (9, 11, 13)	10 101 (9, 11, 14)	18 792 (9, 11, 13)

[a] Each triplet gives the 25th, 50th and 75th sample percentiles of age distribution at the time of examination.

Figure 1. ^{137}Cs contamination levels (Ci/km^2) in the rayons of Zhitomir Oblast as measured in 1992.

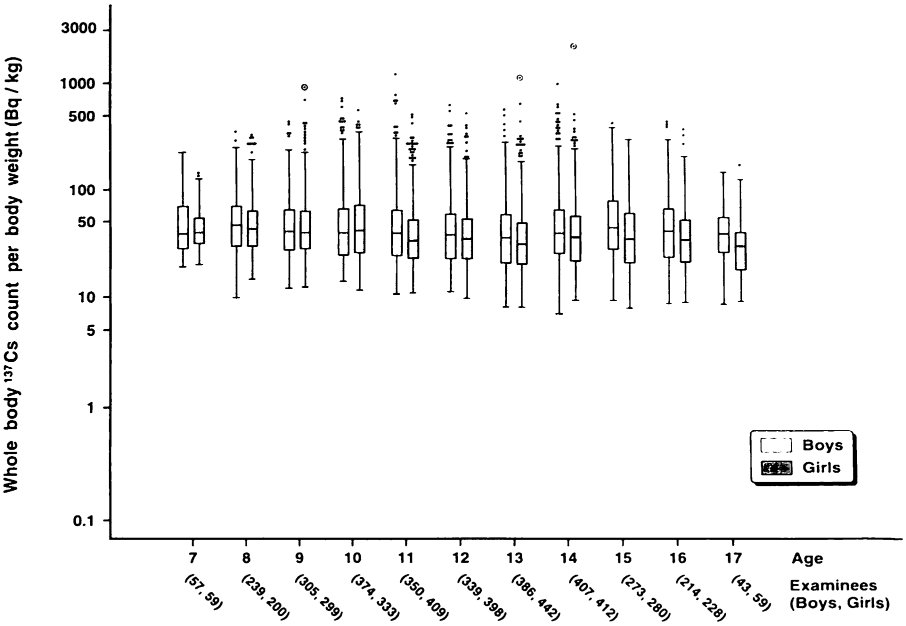

Figure 2. The box-and-whisker plots of whole body ^{137}Cs count per kg body weight by sex and age among children examined in 1994. The children with whole body ^{137}Cs count less than the detection limit (540 Bq) were excluded. The bottom and top ends of the box and the bar inside the box correspond to the 25th, 75th and 50th sample percentiles, respectively. The black dot and the double circle with black dot represent extreme values, called "outside" and "far out," respectively.

among children examined in 1994. The children with whole body ^{137}Cs count less than the detection limit, i.e. 540 Bq, were excluded from the figure. The number of boys and girls excluded in each age group was as follows (girls in parentheses): 7-year, 46(55); 8-year, 126(155); 9-year, 134(164); 10-year, 137(149); 11-year, 96(115); 12-year, 67(72); 13-year, 58(66); 14-year, 31(83); 15-year, 16(42), 16-year, 16(37); and 17-year, 3(5). The median level of ^{137}Cs activity lay between 20 and 100 Bq/kg. The median level of ^{137}Cs specific activity was similar in children from 6 to 16 years old, with the exception of children of 5 years old. In most cases, high ^{137}Cs specific activity prevailed in children of 9, 11 and 13 years old. Boys of 13 and 16 years old showed a higher median level of ^{137}Cs specific activity than girls of the same age.

Figure 3 shows the distribution of ^{137}Cs activity in children's bodies by place of residence on the basis of measurement conducted in the period from 1991 to 1994. The number of children excluded from the figure having whole body ^{137}Cs count less than 540 Bq was as follows: 895 in Korosten City; 376 in Korostenskii; 23 in Luginskii; 11 in Olevskii; 1 in Malinskii; 273 in Emilchinskii; 5 in Ovruchskii; 16 in Narodichskii; and 82 in Volodar-Volinskii Rayons. The maximal activity was registered in residents in the Olevskii, Korostenskii, Luginskii, Ovruchskii and Narodichskii Rayons, while minimal levels were noted in the Volodar-Volinskii and Malinskii Rayons. Ten cases showed ^{137}Cs specific activity exceeding 1,000 Bq/kg, while 36 showed specific activity ranging from 500 to 1,000 Bq/kg.

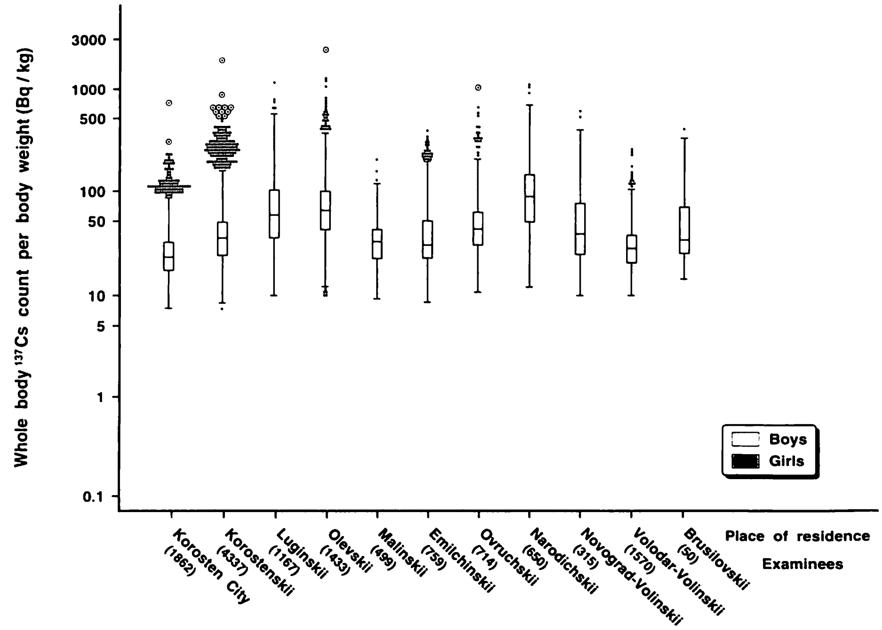

Figure 3. The box-and-whisker plots of whole body ^{137}Cs count per kg body weight by place of residence among children examined from 1991 to 1994. The children with whole body ^{137}Cs count less than the detection limit (540 Bq) were excluded. See Figure 2 for details.

3.3 Thyroid examinations

Figure 4 shows the relationship between thyroid volume and sex and age. An increase in thyroid volume with age in both boys and girls was observed. The figure suggests that the mean volume of the thyroid gland was larger in girls than in boys from 8 to 15 years old.

Figure 5 shows the prevalence of goiter by sex and place of residence. The prevalence of goiter was higher in girls than in boys in all age groups. The largest number of children with goiter was found in the Olevskii, Ovruchskii, Luginskii and Korostenskii Rayons.

Figure 6 shows the prevalence of goiter by sex and ^{137}Cs contamination level in the place of current residence. The prevalence of goiter was higher among girls than among boys in the area with the contamination level ranging from 0 to 25 Ci/km^2. Figure 7 shows the prevalence of goiter by sex and ^{137}Cs contamination level in the place of residence at the time of the accident. The results are similar to those in Figure 6.

Figure 8 shows the prevalence of goiter by sex and ^{137}Cs count per kg body weight. The prevalence of goiter was on the same level in children with a ^{137}Cs count in the range from 50 to 500 Bq/kg. This high percentage of goiter in children is partially due to iodine deficiency in the body, evidence of which has been provided by the investigations into urinary iodine content.

Table 2 shows the number of children with ultrasonographically determined thy-

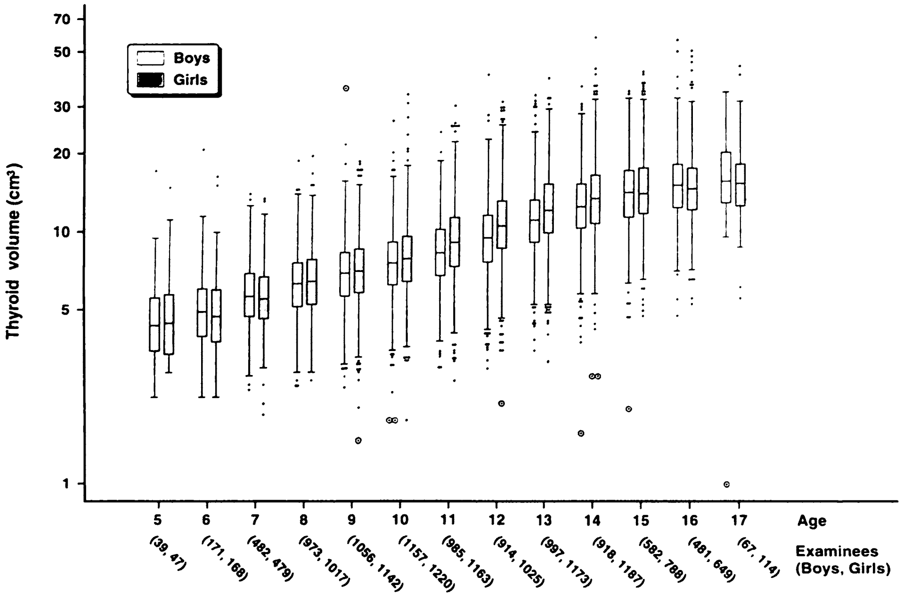

Figure 4. The box-and-whisker plots of thyroid volume by sex and age. See Figure 2 for details.

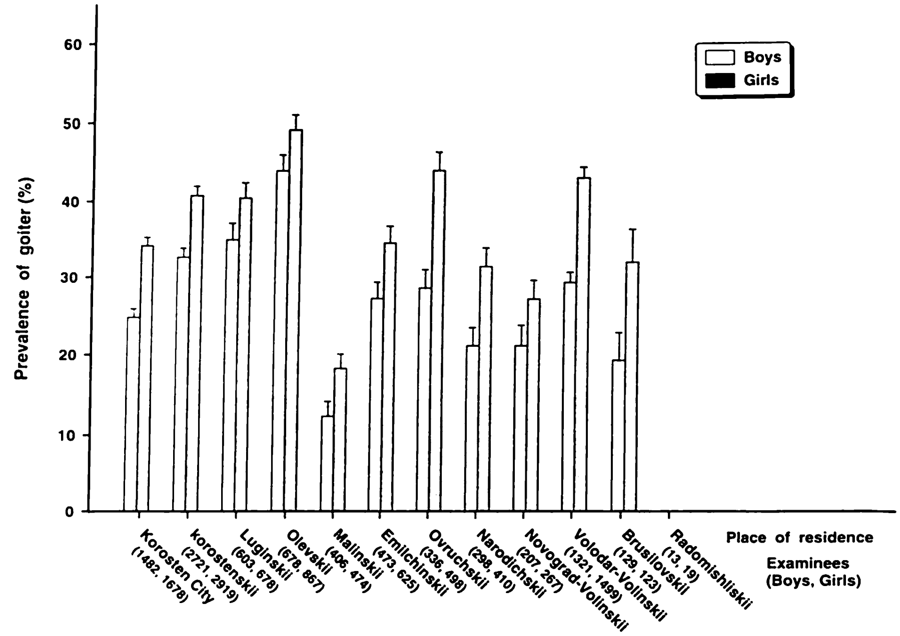

Figure 5. Prevalence of goiter by sex and place of current residence. The whiskers denote the standard errors. See page 104 for the definition of goiter.

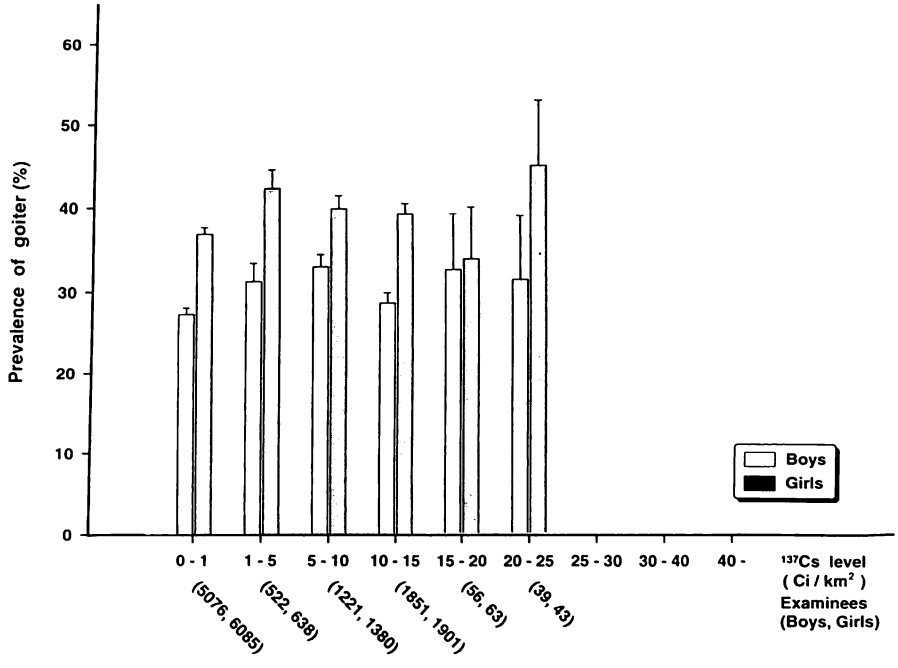

Figure 6. Prevalence of goiter by sex and contamination level (Ci/km^2) in the place of current residence. The whiskers denote the standard errors. See page 104 for the definition of goiter.

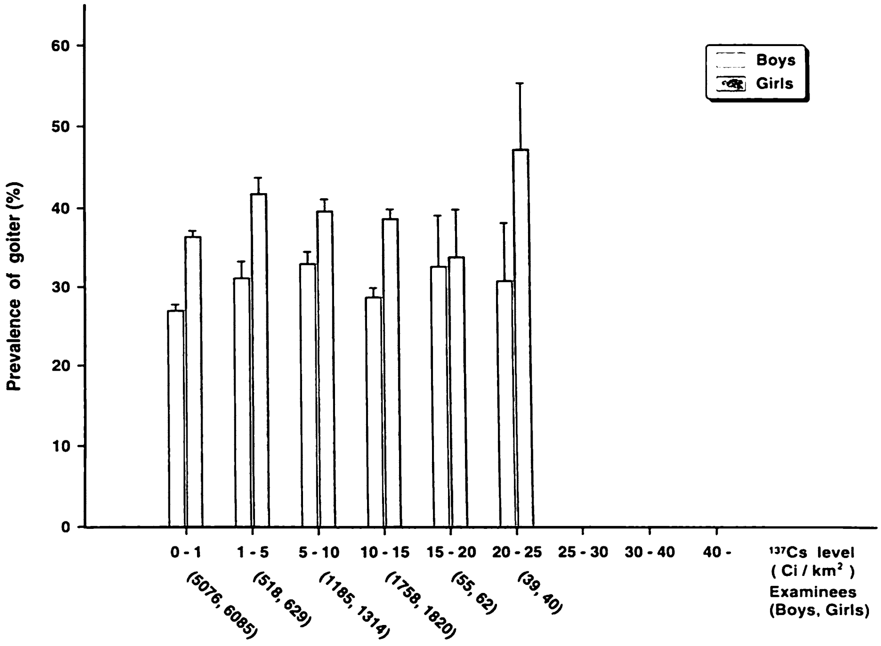

Figure 7. Prevalence of goiter by sex and contamination level (Ci/km^2) in the place of residence at the time of the accident. The whiskers denote the standard errors. See page 104 for the definition of goiter.

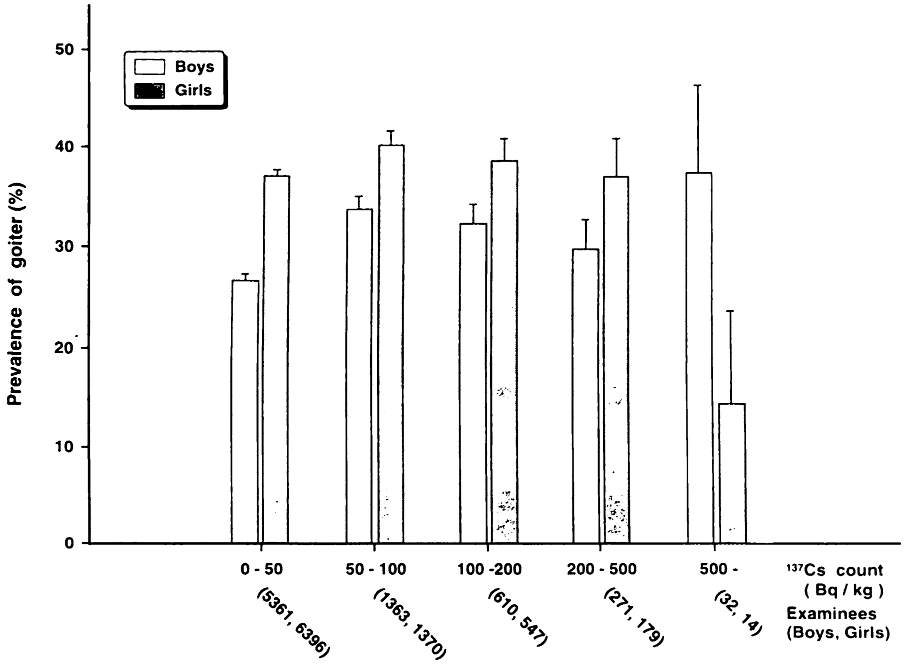

Figure 8. Prevalence of goiter by sex and whole body ^{137}Cs count per kg body weight. The whiskers denote the standard errors. See page 104 for the definition of goiter.

Table 2. Subjects with thyroid abnormalities by sex and place of residence.

Place of residence	Number of subjects examined		Diagnosis: Nodular lesion		Cystic lesion		Abnormal echogenity		Anomaly		Cancer	
	B[a]	G[a]	B	G	B	G	B	G	B	G	B	G
Korosten City	1482	1678	4	7	9	27	1	46	1	4	1	2
Korostenskii	2721	2919	4	7	4	13	4	10	2	3	0	2
Luginskii	603	678	2	1	0	6	3	7	0	0	0	0
Olevskii	678	867	4	3	4	7	2	10	0	0	0	0
Malinskii	406	474	0	0	0	2	1	1	1	0	0	0
Emilchinskii	473	625	0	2	1	1	1	8	1	1	0	0
Ovruchskii	336	498	1	4	0	1	1	5	0	0	0	0
Narodichskii	298	410	0	3	2	3	1	1	0	0	0	0
Novograd-Volinskii	207	267	0	2	0	3	1	2	0	1	0	0
Volodar-Volinskii	1321	1499	0	8	0	13	2	17	3	1	0	0
Brusilovskii	129	123	0	0	0	0	0	0	0	0	0	0
Radomishliskii	13	19	0	0	3	1	0	0	0	0	0	0
Total	8667	10 057	15	37	23	77	17	107	8	10	1	4

[a] B, boys, G, girls.

roid abnormalities by sex and place of residence. Nodular lesions were found in 52 (0.28%) children (15 boys and 37 girls). Thyroid cancer was found in 5 (0.02%) children (1 boy and 4 girls). Four of these cases were diagnosed with echo-guided FNA biopsy. The final diagnosis was confirmed histologically at operation as papillary carcinoma. All children underwent surgery at the Kiev Research Intstitute of Endocrinology and Metabolism. Cystic lesions were found in 100 (0.53%) children (23 boys and 77 girls). Abnormal echogenity (suspected either adenomatous goiter or autoimmune thyroiditis) was found in 124 (0.65%) children (17 boys and 107 girls). Thyroid anomaly (atrophy or asymmetry) was found in 18 children (0.1%) (8 boys and 10 girls).

Table 3 shows the prevalence of positive ATG and AMC titers by sex and place of residence. Girls displayed positive titers of ATG and AMC antibodies more frequently in all the rayons under study. The prevalence of positive titers of ATG and AMC antibodies was in the range of 3.1 to 3.5%. A high percentage of positive titers, particularly of ATG, was noted in three rayons: Novograd-Volinskii, Narodichskii and Ovruchskii Rayons.

Figure 9 shows the prevalence of positive ATG titers by sex and ^{137}Cs specific activity per kg body weight. No statistically significant relationship was observed between the prevalence of positive ATG titers and specific ^{137}Cs concentration in the body. Figure 10 shows the prevalence of ATG titers by sex and ^{137}Cs contamination level in the place of current residence. A relatively high prevalence of ATG titers was observed in places with a ^{137}Cs contamination level in the range from 0 to 1 Ci/km^2. Girls displayed higher prevalence than boys. Figure 11 shows the prevalence of positive ATG titers by sex and ^{137}Cs contamination level in the place of residence at the time of the accident. The results are similar to those in Figure 10.

Table 3. Prevalence of positive ATG (anti-thyroglobulin antibody) and AMC (anti-microsome antibody) titers by sex and place of residence.[a]

Place of residence	Number of subjects measured			Antibody					
				Anti-thyroglobulin			Anti-microsome		
	Total	Boys	Girls	Total	Boys	Girls	Total	Boys	Girls
Korosten City	2728	1284	1444	79	23	56	101	24	77
				(2.9)	(1.8)	(3.9)	(3.7)	(1.9)	(5.3)
Korostenskii	5522	2666	2856	158	58	100	160	37	123
				(2.9)	(2.2)	(3.5)	(2.9)	(1.4)	(4.3)
Luginskii	1174	547	627	39	15	24	37	12	25
				(3.3)	(2.7)	(3.8)	(3.2)	(2.2)	(3.9)
Olevskii	1438	628	810	36	8	28	43	10	33
				(2.5)	(1.3)	(3.5)	(3.0)	(1.6)	(4.1)
Malinskii	728	340	388	17	2	15	21	6	15
				(2.3)	(0.6)	(3.9)	(2.9)	(1.8)	(3.9)
Emilchinskii	926	406	520	36	14	22	40	15	25
				(3.9)	(3.4)	(4.2)	(4.3)	(3.7)	(4.8)
Ovruchskii	565	223	342	27	9	18	41	12	29
				(4.7)	(4.0)	(5.3)	(7.3)	(5.4)	(8.5)
Narodichskii	613	268	345	41	17	24	40	17	23
				(6.7)	(6.3)	(7.0)	(6.5)	(6.3)	(6.7)
Novograd-Volinskii	355	163	192	45	20	25	17	7	10
				(12.7)	(12.3)	(13.0)	(4.8)	(4.3)	(5.2)
Volodar-Volinskii	2800	1313	1487	47	8	39	77	13	64
				(1.7)	(0.6)	(2.6)	(2.8)	(0.9)	(4.3)
Brusilovskii	251	128	123	10	2	8	14	4	10
				(3.9)	(1.6)	(6.5)	(5.6)	(3.1)	(8.1)
Radomishliskii	1	0	1	0	0	0	0	0	0
Total	17 101	7966	9135	535	176	359	591	157	434
				(3.1)	(2.2)	(3.9)	(3.5)	(2.0)	(4.8)

[a] Number of subjects with percentages in parentheses.

Figure 12 shows the prevalence of positive AMC titers by sex and whole body ^{137}Cs count per kg body weight. No correlation was observed. Figure 13 shows the prevalence of positive AMC titers by sex and ^{137}Cs contamination level in the place of current residence. No correlation was observed. Figure 14 shows the prevalence of positive AMC titers by sex and ^{137}Cs contamination level in the place of residence at the time of the accident. No correlation was observed.

Table 4 presents the number of children with simultaneously high TSH and low FT_4 levels (hypothyroidism) by sex and place of residence. A total of 24 children (17 girls and 7 boys) were diagnosed as chemical hypothyroidism. The table also shows the cases with simultaneously low TSH and high FT_4 levels (hyperthyroidism). A total of 14 cases (12 girls and 2 boys) were found, and all of them are carefully followed and treated.

Scatter plots of urinary iodine content and FT_4 level (Figure 15) and TSH level (Figure 16) for 659 subjects measured at Kiev Center indicate that urinary iodine content was not correlated with either FT_4 level (95% confidence interval of the cor-

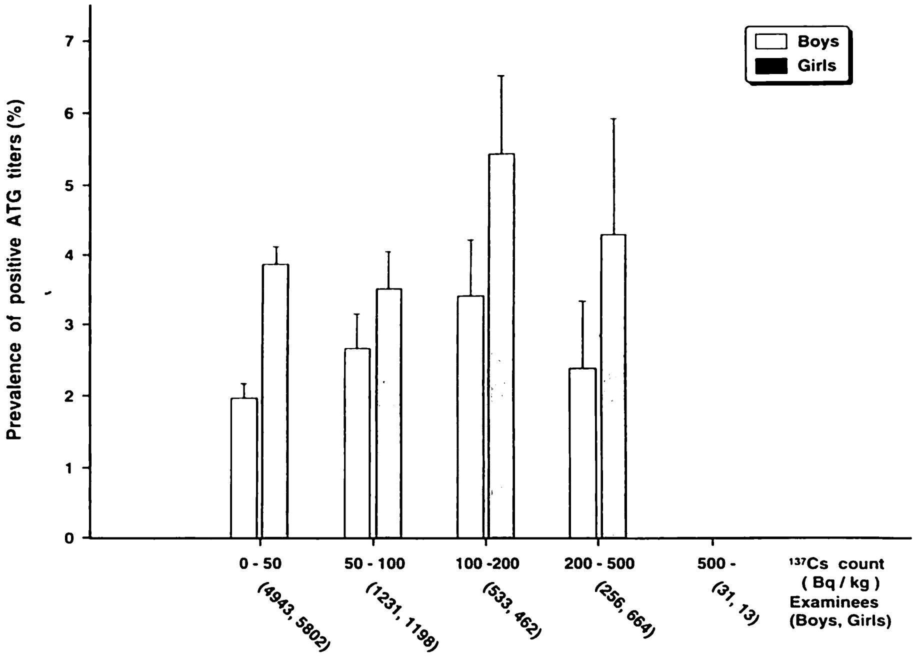

Figure 9. Prevalence of positive ATG titers by sex and whole body ^{137}Cs count per kg body weight. The whiskers denote the standard errors.

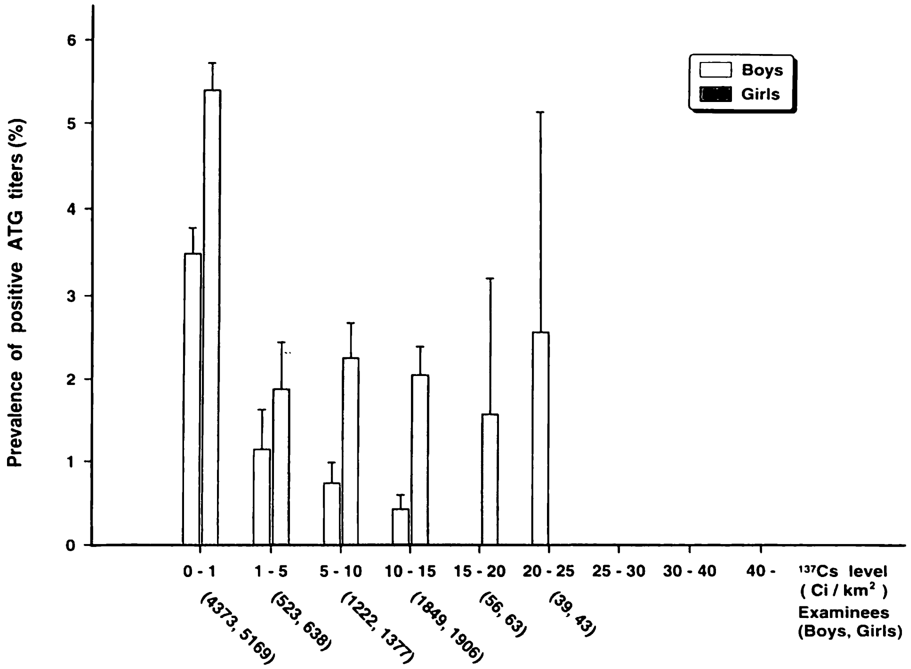

Figure 10. Prevalence of positive ATG titers by sex and contamination level (Ci/km^2) in the place of current residence. The whiskers denote the standard errors.

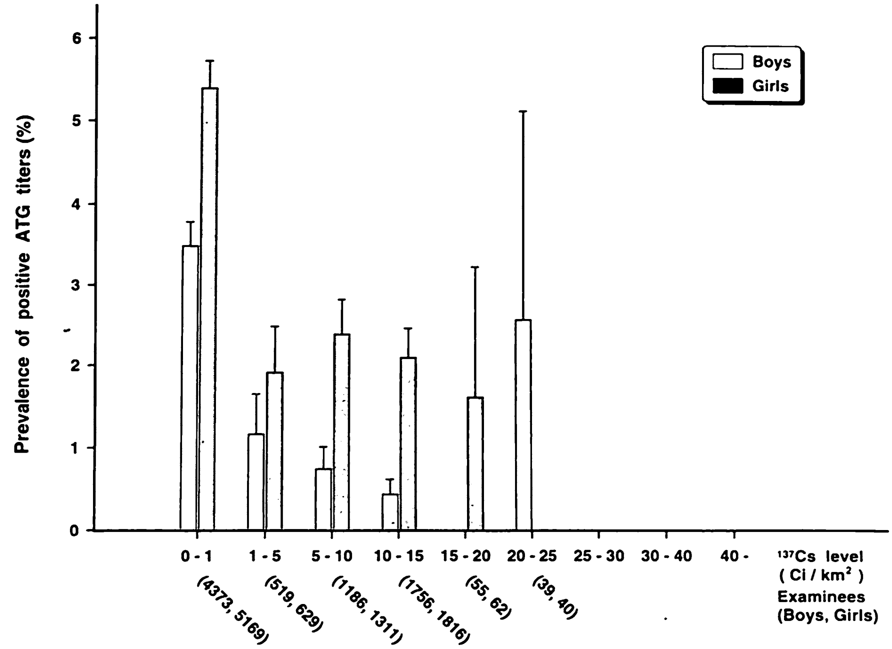

Figure 11. Prevalence of positive ATG titers by sex and contamination level (Ci/km^2) in the place of residence at the time of the accident. The whiskers denote the standard errors.

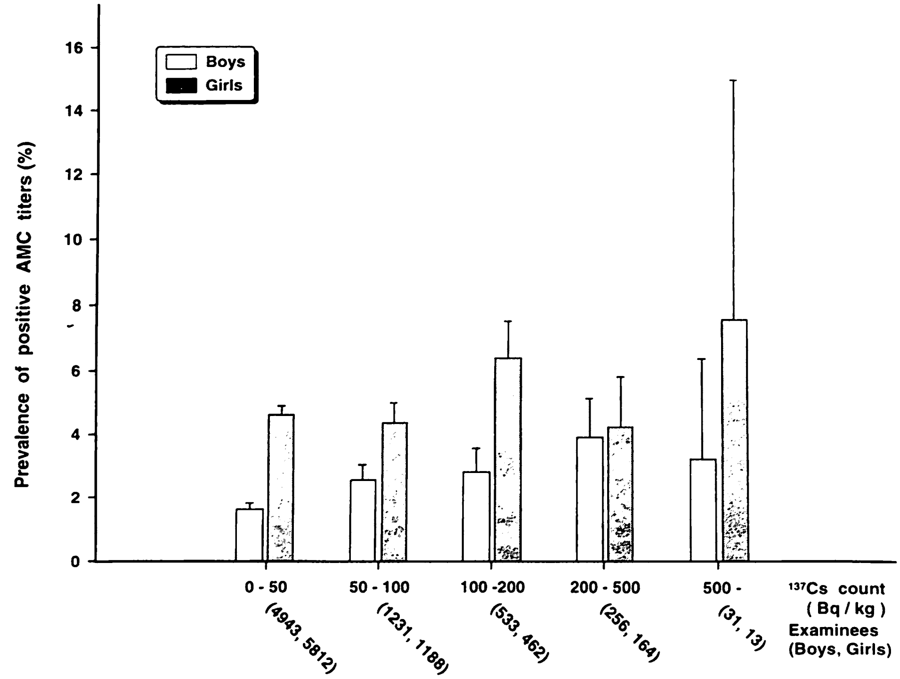

Figure 12. Prevalence of positive AMC titers by sex and whole body ^{137}Cs count per kg body weight. The whiskers denote the standard errors.

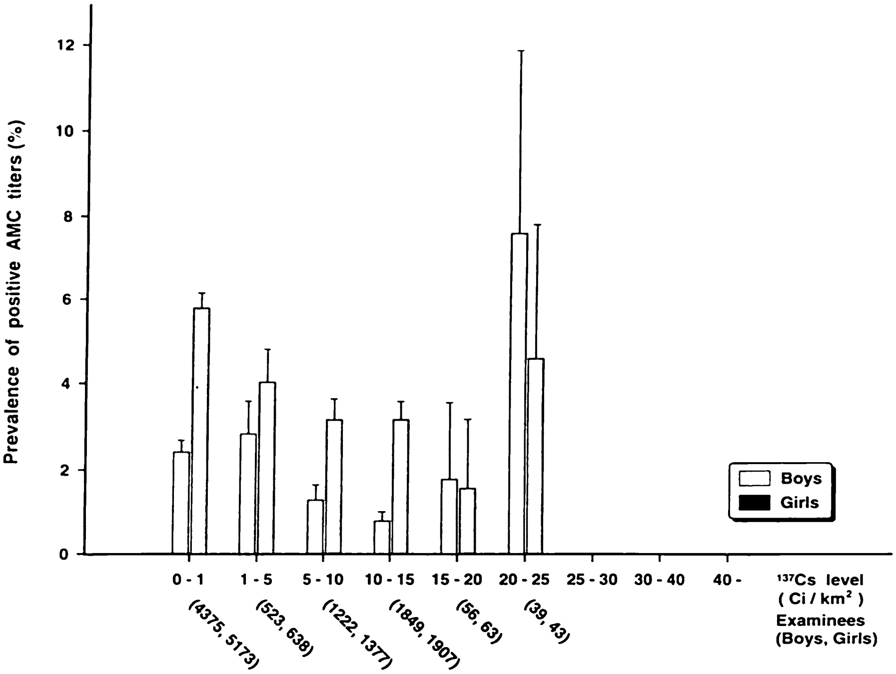

Figure 13. Prevalence of positive AMC titers by sex and contamination level (Ci/km^2) in the place of current residence. The whiskers denote the standard errors.

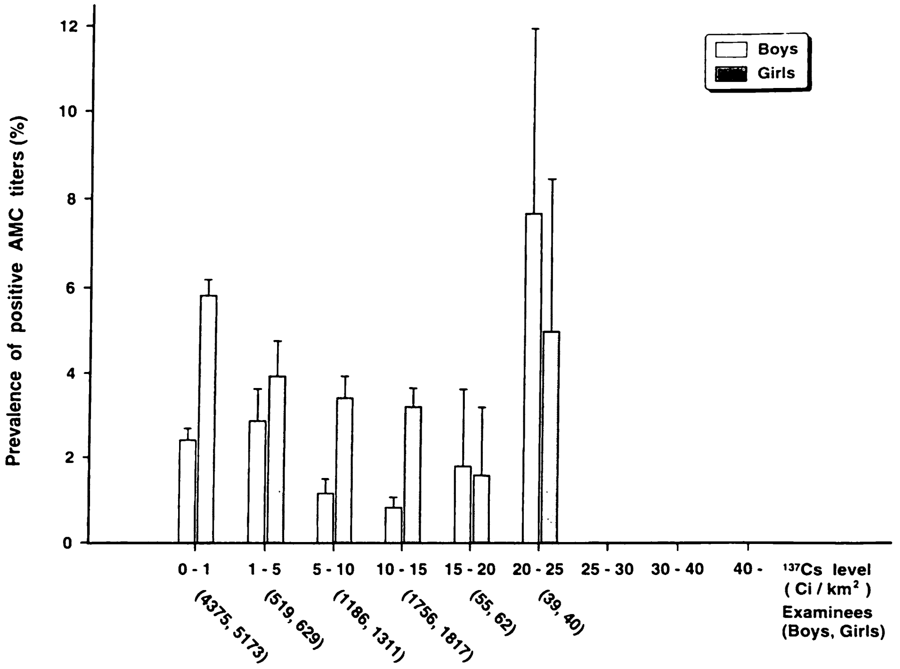

Figure 14. Prevalence of positive AMC titers by sex and contamination level (Ci/km^2) in the place of residence at the time of the accident. The whiskers denote the standard errors.

Table 4. Number of subjects with hypothyroidism and hyperthyroidism by sex and place of residence.

Place of residence	Number of subjects with measurement			Hypothyroidism[a]			Hyperthyroidism[b]		
	Total	Boys	Girls	Total	Boys	Girls	Total	Boys	Girls
Korosten City	3161	1483	1678	6	1	5	2	0	2
Korostenskii	5650	2727	2923	7	3	4	4	1	3
Luginskii	1280	603	677	3	0	3	1	1	0
Olevskii	1546	679	867	1	1	0	3	0	3
Malinskii	880	406	474	0	0	0	0	0	0
Emilchinskii	1114	476	638	1	0	1	0	0	0
Ovruchski	864	347	517	1	1	0	0	0	0
Narodichskii	708	298	410	0	0	0	0	0	0
Novograd-Volinskii	474	207	267	0	0	0	0	0	0
Volodar-Volinskii	2819	1321	1498	5	1	4	4	0	4
Brusilovskii	252	129	123	0	0	0	0	0	0
Radomishliskii	32	13	19	0	0	0	0	0	0
Total	18 780	8689	10 091	24	7	17	14	2	12

[a] Diagnosed when free $T_4 < 10.0$ pmol/L and TSH > 2.90 μIU/mL.

[b] Diagnosed when free $T_4 > 25.0$ pmol/L and TSH < 0.24 μIU/mL.

relation coefficient: $-0.006 < \rho < 0.15$) or TSH level (95% confidence interval of the correlation coefficient: $-0.12 < \rho < 0.04$). Figure 17 shows the relationship between the residual thyroid volume after adjustment for age, height and weight, calculated with the help of the formula for goiter, and urinary iodine content. No correlation was

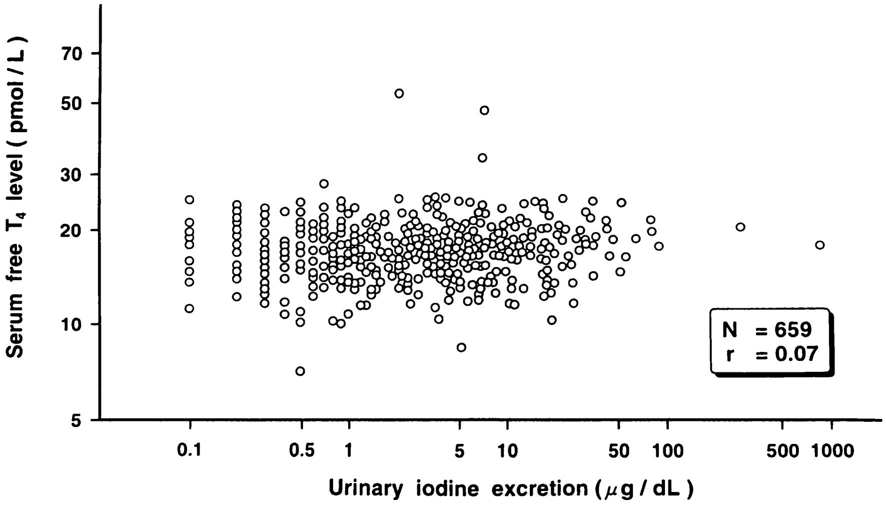

Figure 15. Scatter plots of urinary iodine excretion and serum free T_4 level.

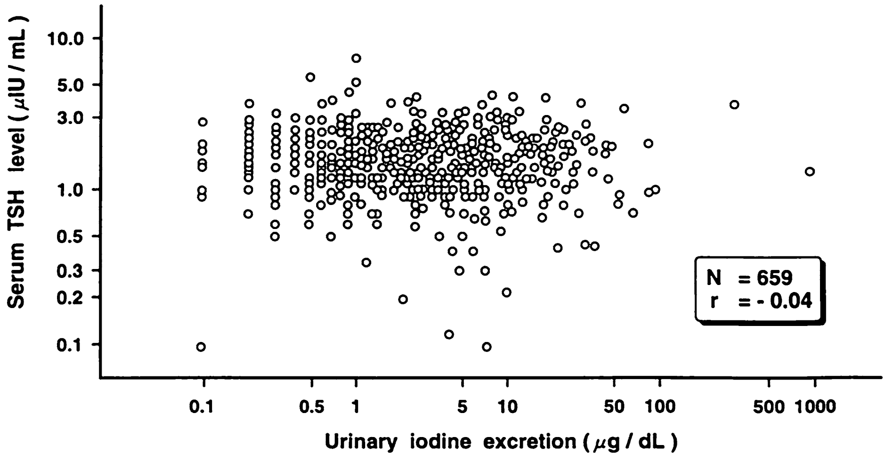

Figure 16. Scatter plots of urinary iodine excretion and serum TSH level.

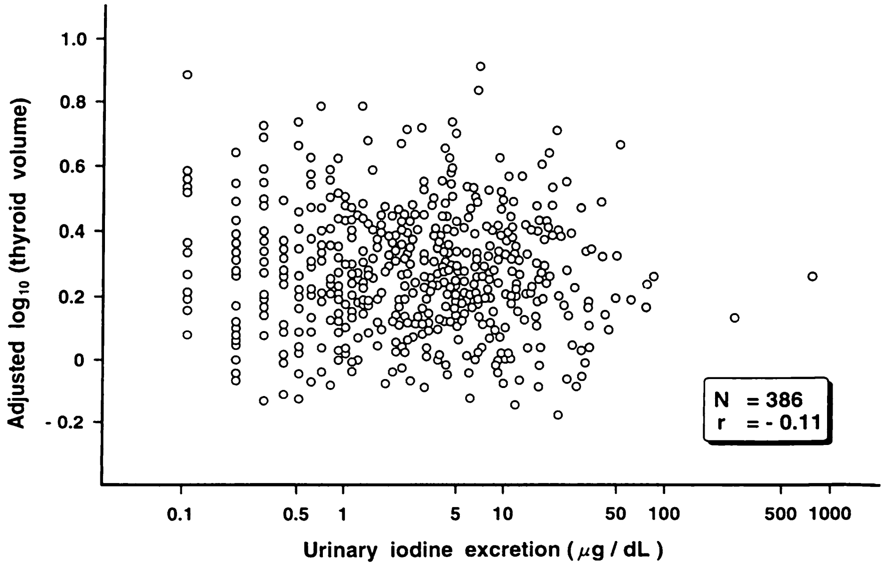

Figure 17. Scatter plots of urinary iodine excretion and the residual of the logarithm of thyroid volume after adjustment for age, height and weight.

observed between the two quantities. The 95% confidence interval of the correlation coefficient was $-0.12 < \rho < 0.04$. All figures show low levels of urinary iodine content, which may be attributable to the fact that this region is considered endemic goiter.

3.4 Hematological studies

Figure 18 shows the hemoglobin levels in the blood by age and sex. The median of Hb level was within normal limits in all age groups. However, it should be noted that girls aged 12–16 showed a decrease in the median of Hb level whereas boys of the same age showed an increase in Hb level. We consider these changes to be associated with hormonal changes during puberty. A reduction in Hb level in the blood below the normal range was found in 29 (0.3%) boys and 54 (0.5%) girls. An increase in the Hb level in the blood above the normal range was registered in 17 children.

Figure 19 shows the relationship between MCV and age and sex. The median of MCV in all age groups was within the normal range in both boys and girls. It should be noted that MCV was higher in girls than in boys in all age groups. The lowest levels were 62.2 fl/Hb 92 g/L; 66.0 fl/Hb 88 g/L and 68.0 fl/Hb 79 g/L.

Ferritin measurements were carried out using blood serum of children with Hb level < 110 g/L and MCV < 80 fl (Figures 20 and 21). A ferritin level below normal limits was observed in 11.3% of the 344 tests performed.

Figure 22 shows that the median value of WBC was within normal limits in both boys and girls of all ages. An increase in WBC was registered in 656 (3.5%) of the children at the time of the examination. This disorder may be caused by acute respi-

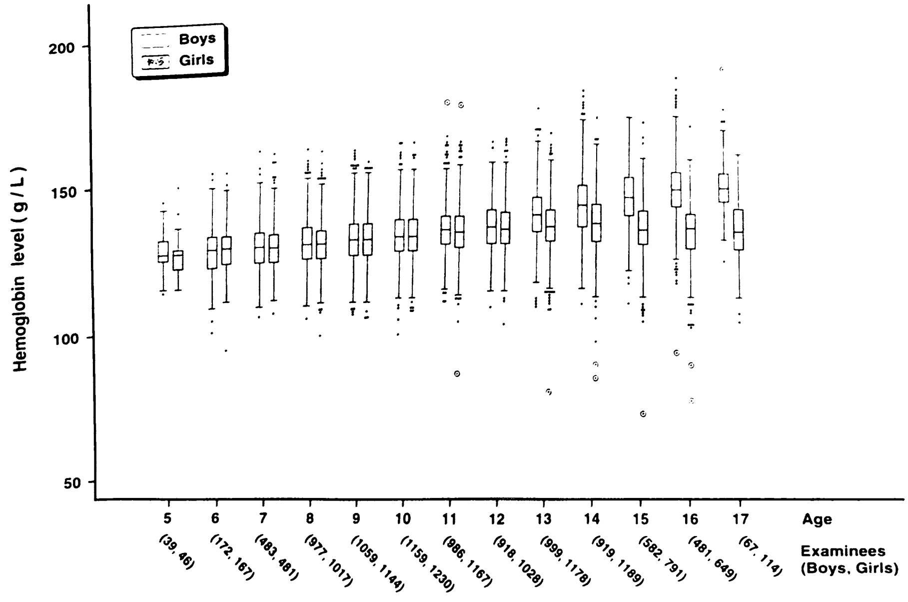

Figure 18. The box-and-whisker plots of hemoglobin level by sex and age. See Figure 2 for details.

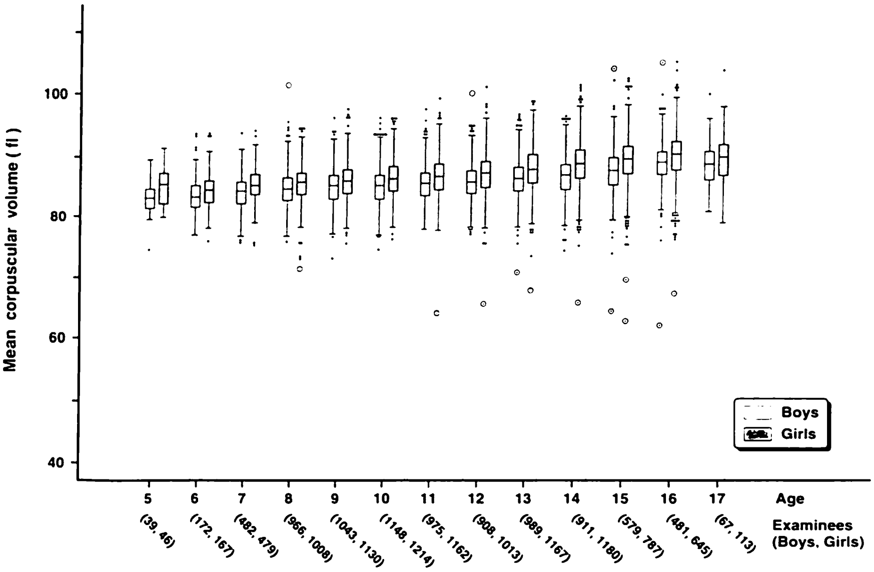

Figure 19. The box-and-whisker plots of mean corpuscular volume by sex and age. See Figure 2 for details.

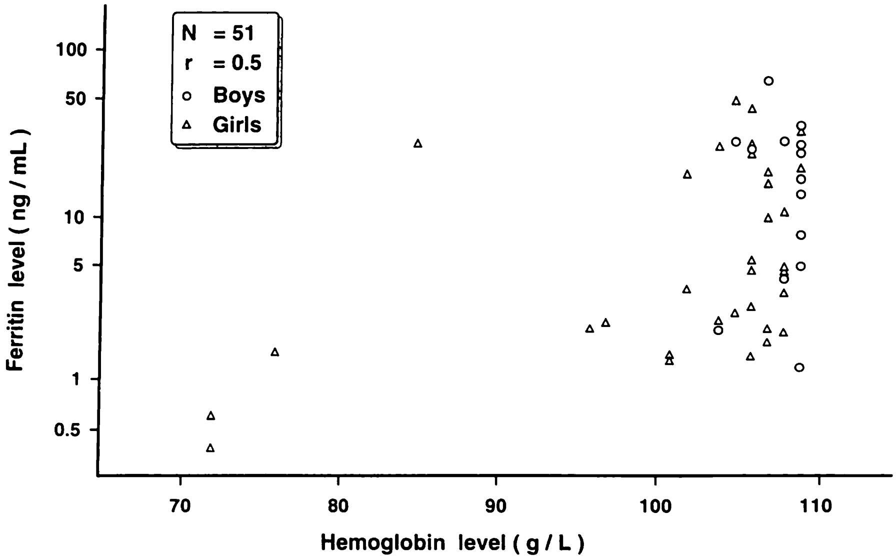

Figure 20. Scatter plots of hemoglobin (Hb) and ferritin levels in children with Hb less than 110 g/L.

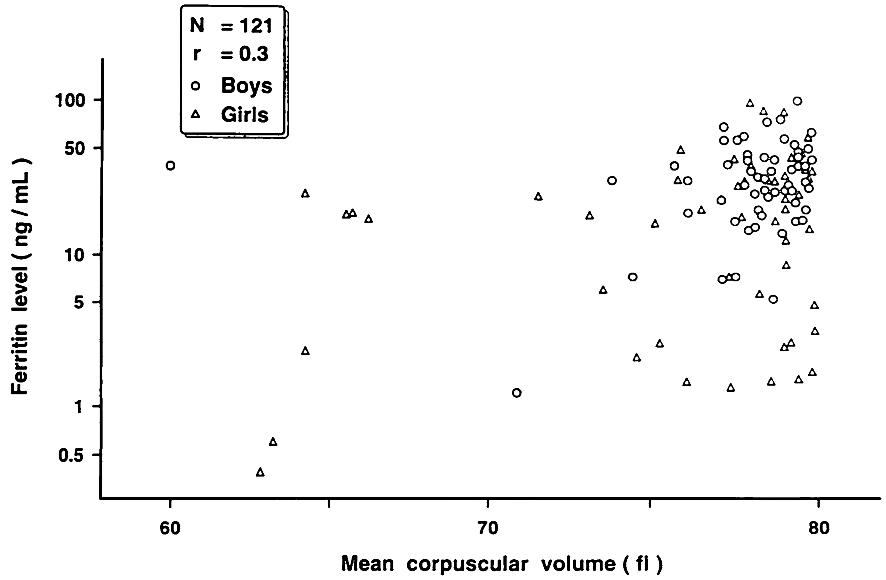

Figure 21. Scatter plots of mean corpuscular volume (MCV) and ferritin levels in children with MCV less than 80 fl.

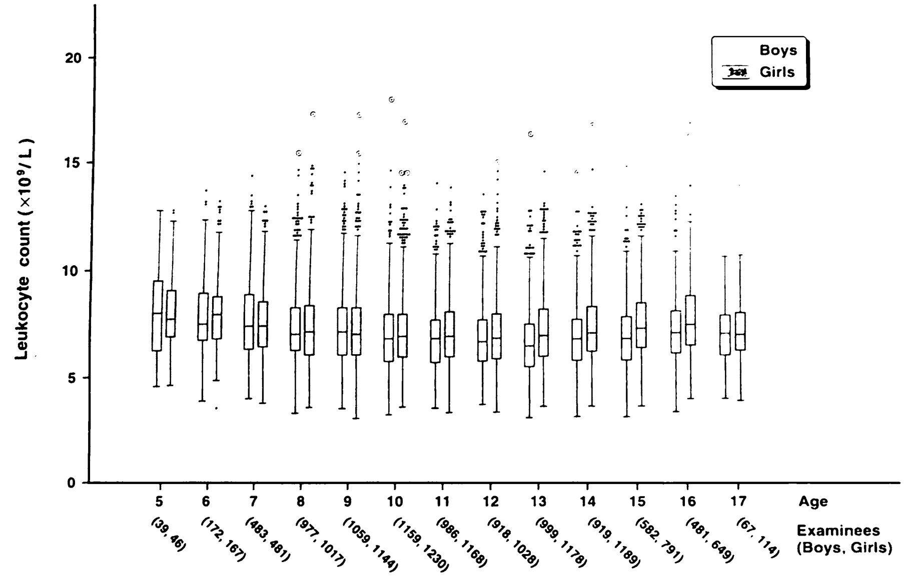

Figure 22. The box-and-whisker plots of leukocyte count by sex and age. See Figure 2 for details.

ratory illness, tonsillitis or influenza at the time of the initial examination. Leukopenia was found in 25 boys and 4 girls.

The assessment of the relationship between the neutrophil count and age and sex showed that the median of the neutrophil count was within normal limits. Neutropenia and neutrophilia were registered in 58 and 954 children, respectively.

Figure 23 shows the relationship between PLT and age and sex. The median of PLT was within the normal range. There was a trend toward a decrease in PLT with age. Thrombocytopenia was found in 7 girls and 8 boys. Four subjects were found to have Werlhof's disease. Children with thrombocytopenia are under the observation of a hematologist. Thrombocytosis was found in 188 children, 100 of whom were girls.

A total of 3,485 examined children (18.5%) showed eosinophilia, 1,865 of whom were girls. An analysis was conducted on some of the cases to define the causes of eosinophilia. This revealed that the prevalence of eosinophilia was high in children with frequent respiratory diseases and bronchitis accompanied by an asthmatic component in their history. Some children developed an allergic reaction to drugs. Some children were found to be suffering from helminthic invasion. A number of children had allergic dermatitis. Some healthy children also showed eosinophilia of unknown cause.

The medians of lymphocyte count were within normal limits. Lymphocytosis was found in 896 girls and 684 boys. Lymphopenia was registered in 109 girls and 95 boys.

Tables 5A and 5B present the hematological abnormalities by whole body ^{137}Cs count per kg body weight. The group of children with a ^{137}Cs specific activity ranging

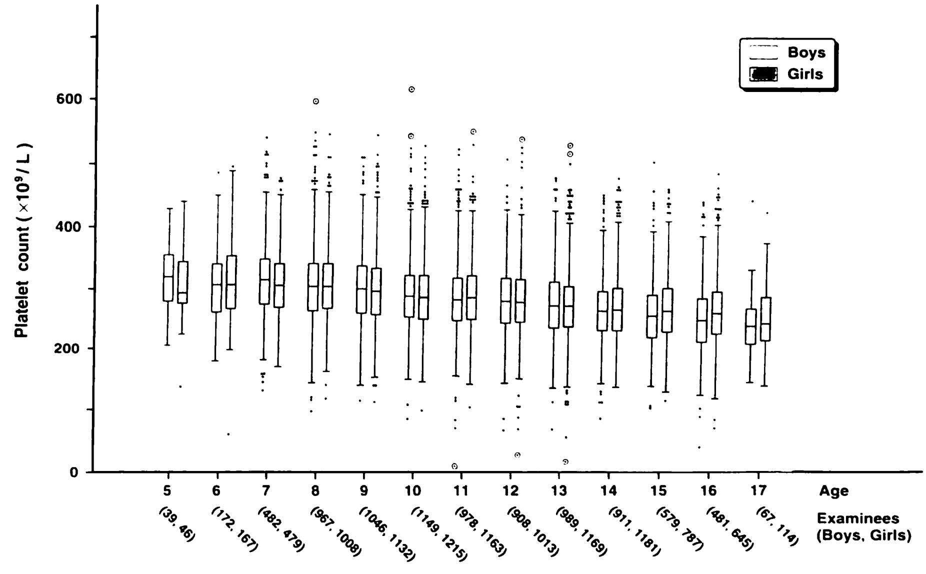

Figure 23. The box-and-whisker plots of platelet count by sex and age. See Figure 2 for details.

Table 5A. Frequency of boys with hematological abnormalities by ^{137}Cs level.[a]

Blood analysis		Whole body ^{137}Cs count per body weight (Bq/kg)					Total
Item (unit)[b]	Abnormality criteria	0–50	50–100	100–200	200–500	500–	
Hb (g/L)	<110	21 (0.3)	4 (0.3)	4 (0.7)			29 (0.3)
	>180		1 (0.1)		1 (0.4)		2 (0.0)
WBC (x10^9/L)	<3.8	21 (0.3)	3 (0.2)	1 (0.2)			25 (0.3)
	>10.6	248 (3.8)	48 (3.5)	27 (4.5)	18 (6.6)	3 (9.4)	344 (3.9)
PLT (x10^9/L)	<100	8 (0.1)			1 (0.4)		9 (0.1)
	>440	74 (1.1)	10 (0.7)	4 (0.7)	1 (0.4)		89 (1.0)
MCV (fl)	<80	171 (2.6)	36 (2.6)	21 (3.5)	10 (3.7)		238 (2.7)
	>100	4 (0.1)					4 (0.0)
Ly (x10^9/L)	<1.2	60 (0.9)	22 (1.6)	9 (1.5)	5 (1.8)	1 (3.1)	97 (1.1)
	>3.5	525 (8.0)	95 (6.9)	45 (7.4)	23 (8.5)	2 (6.3)	690 (7.8)
Ne (x10^9/L)	<1.4	22 (0.3)	5 (0.4)	1 (0.2)			28 (0.3)
	>6.6	257 (3.9)	56 (4.1)	28 (4.6)	19 (7.0)	3 (9.4)	363 (4.1)
Eo (x10^9/L)	>0.5	1195 (18.2)	263 (19.1)	110 (18.2)	60 (22.1)	6 (18.8)	1634 (18.5)
Mo (x10^9/L)	<0.12	158 (2.4)	29 (2.1)	10 (1.7)	4 (1.5)	1 (3.1)	202 (2.3)
	>1.00	96 (1.5)	19 (1.4)	13 (2.1)	4 (1.5)	1 (3.1)	133 (1.5)
Number of children measured		6557	1375	606	271	32	8841

[a] Parenthetic entries refer to the percentage of the subjects while empty spaces denote the absence of subjects with abnormalities.

[b] Hb, hemoglobin; WBC, white blood cell (leukocyte); PLT, platelet; MCV, mean corpuscular volume; Ly, lymphocyte; Ne, neutrophil; Eo, eosinophil; Mo, monocyte.

Table 5B. Frequency of girls with hematological abnormalities by ^{137}Cs level.[a]

Blood analysis		Whole body ^{137}Cs count per body weight (Bq/kg)					Total
Item (unit)[b]	Abnormality criteria	0–50	50–100	100–200	200–500	500–	
Hb (g/L)	<110	41 (0.5)	9 (0.7)	3 (0.5)	1 (0.6)		54 (0.5)
	>160	12 (0.1)	1 (0.1)		1 (0.6)		14 (0.1)
WBC (x10^9/L)	<3.6	7 (0.1)					7 (0.1)
	>11.0	236 (2.9)	54 (3.9)	16 (2.9)	6 (3.4)		312 (3.1)
PLT (x10^9/L)	<100	3 (0.0)	4 (0.3)				7 (0.1)
	>440	87 (1.1)	11 (0.8)	1 (0.2)	2 (1.1)		101 (1.0)
MCV (fl)	<80	110 (1.4)	23 (1.7)	7 (1.3)	2 (1.1)		142 (1.4)
	>100	13 (0.2)	4 (0.3)				17 (0.2)
Ly (x10^9/L)	<1.2	82 (1.0)	21 (1.5)	7 (1.3)	2 (1.1)		112 (1.1)
	>3.5	684 (8.5)	133 (9.7)	60 (10.9)	20 (11.2)	1 (7.1)	898 (8.8)
Ne (x10^9/L)	<1.4	28 (0.3)	2 (0.1)				30 (0.3)
	>6.6	465 (5.8)	97 (7.1)	28 (5.1)	8 (4.5)		598 (5.9)
Eo (x10^9/L)	>0.5	1468 (18.2)	270 (19.6)	105 (19.1)	28 (15.7)	5 (35.7)	1876 (18.4)
Mo (x10^9/L)	<0.12	155 (1.9)	33 (2.4)	14 (2.5)	7 (3.9)		209 (2.0)
	>1.00	122 (1.5)	23 (1.7)	5 (0.9)	3 (1.7)		153 (1.5)
Number of children measured		8084	1375	551	178	14	10 202

[a] Parenthetic entries refer to the percentage of the subjects while empty spaces denote the absence of subjects with abnormalities.

[b] Hb, hemoglobin; WBC, white blood cell (leukocyte); PLT, platelet; MCV, mean corpuscular volume; Ly, lymphocyte; Ne, neutrophil; Eo, eosinophil; Mo, monocyte.

Table 6A. Frequency of boys with hematological abnormalities by place of residence.[a]

Blood analysis		Place of residence[b]												Total
Item (unit)[c]	Abnormality criteria	KOR	KRR	LUG	OLE	MAL	EMI	OVR	NAR	NVL	VVL	BRU	RAD	
Hb (g/L)	< 110		10 (0.4)		3 (0.4)	3 (0.7)	3 (0.6)	1 (0.3)			9 (0.7)			29 (0.3)
	> 180		1 (0.0)		1 (0.1)									2 (0.0)
WBC ($\times10^9$/L)	< 3.8	7 (0.5)	4 (0.1)	2 (0.3)	3 (0.4)	2 (0.5)			1 (0.3)	3 (1.4)	2 (0.2)			24 (0.3)
	> 10.6	49 (3.3)	64 (2.3)	26 (4.3)	29 (4.3)	12 (3.0)	23 (4.8)	21 (6.1)	13 (4.4)	12 (5.8)	74 (5.6)	14 (10.9)	4 (30.8)	341 (3.9)
PLT ($\times10^9$/L)	< 100		1 (0.0)		1 (0.1)		1 (0.2)				5 (0.4)			8 (0.1)
	> 440	14 (0.9)	25 (0.9)	6 (1.0)	4 (0.6)	11 (2.7)	5 (1.1)	5 (1.4)	1 (0.3)	1 (0.5)	14 (1.1)	1 (0.8)	1 (7.7)	88 (1.0)
MCV (fl)	< 80	31 (2.1)	50 (1.8)	15 (2.5)	33 (4.9)	11 (2.7)	37 (7.8)	9 (2.6)	6 (2.0)	6 (2.9)	35 (2.7)	4 (3.1)		237 (2.7)
	> 100		1 (0.0)	2 (0.3)							1 (0.1)			4 (0.0)
Ly ($\times10^9$/L)	< 1.2	11 (0.7)	24 (0.9)	9 (1.5)	16 (2.4)	9 (2.2)	7 (1.5)	2 (0.6)	8 (2.7)	3 (1.4)	4 (0.3)	2 (1.6)		95 (1.1)
	> 3.5	123 (8.3)	130 (4.8)	44 (7.3)	66 (9.7)	42 (10.3)	58 (12.2)	35 (10.1)	15 (5.0)	35 (16.9)	113 (8.6)	15 (11.6)	8 (61.5)	684 (7.9)
Ne ($\times10^9$/L)	< 1.4	13 (0.9)	5 (0.2)	2 (0.3)		3 (0.7)		1 (0.3)	1 (0.3)	1 (0.5)	2 (0.2)			28 (0.3)
	> 6.6	44 (3.0)	87 (3.2)	24 (4.0)	32 (4.7)	15 (3.7)	23 (4.8)	14 (4.0)	19 (6.4)	6 (2.9)	83 (6.3)	9 (7.0)	2 (15.4)	358 (4.1)
Eo ($\times10^9$/L)	> 0.5	226 (15.2)	289 (10.6)	172 (28.6)	135 (19.9)	139 (34.2)	134 (28.2)	87 (25.1)	51 (17.1)	76 (36.7)	260 (19.7)	42 (32.6)	9 (69.2)	1620 (18.6)
Mo ($\times10^9$/L)	< 0.12	38 (2.6)	66 (2.4)	15 (2.5)	15 (2.2)	13 (3.2)	15 (3.2)	9 (2.6)	2 (0.7)	2 (1.0)	17 (1.3)	2 (1.6)		194 (2.2)
	> 1.00	31 (2.1)	15 (0.6)	20 (3.3)	11 (1.6)	5 (1.2)	9 (1.9)	10 (2.9)	4 (1.3)	2 (1.0)	18 (1.4)	6 (4.7)	2 (15.4)	133 (1.5)
Number of children measured		1483	2727	602	679	406	476	347	298	207	1320	129	13	8687

[a] Parenthetic entries refer to the percentage of the subjects while empty spaces denote the absence of subjects with abnormalities.

[b] KOR, Korosten City; KRR, Korostenskii; LUG, Luginskii; OLE, Olevskii; MAL, Malinskii; EMI, Emilchinskii; OVR, Ovruchskii; NAR, Narodichskii; NVL, Novograd-Volinskii; VVL, Volodar-Volinskii; BRU, Brusilovskii; RAD, Radomishliskii.

[c] Hb, hemoglobin; WBC, white blood cell (leukocyte); PLT, platelet; MCV, mean corpuscular volume; Ly, lymphocyte; Ne, neutrophil; Eo, eosinophil; Mo, monocyte.

Table 6B. Frequency of girls with hematological abnormalities by place of residence.[a]

Blood analysis		Place of residence[b]												Total
Item (unit)[c]	Abnormality criteria	KOR	KRR	LUG	OLE	MAL	EMI	OVR	NAR	NVL	VVL	BRU	RAD	
Hb (g/L)	< 110	5 (0.3)	17 (0.6)	4 (0.6)	7 (0.8)	3 (0.6)	1 (0.2)	3 (0.6)	3 (0.7)		10 (0.7)	1 (0.8)		54 (0.5)
	> 160	5 (0.3)	4 (0.1)			1 (0.2)	1 (0.2)	1 (0.2)			1 (0.1)			13 (0.1)
WBC (×10⁹/L)	< 3.6	1 (0.1)	4 (0.1)							1 (0.4)	1 (0.1)			7 (0.1)
	> 11.0	34 (2.0)	54 (1.8)	18 (2.7)	23 (2.7)	14 (3.0)	19 (3.0)	30 (5.8)	13 (3.2)	12 (4.5)	81 (5.4)	8 (6.5)	6 (31.6)	312 (3.1)
PLT (×10⁹/L)	< 100	1 (0.1)	1 (0.0)	1 (0.1)					1 (0.2)		3 (0.2)			7 (0.1)
	> 440	12 (0.7)	26 (0.9)	4 (0.6)	5 (0.6)	5 (1.1)	5 (0.8)	4 (0.8)	5 (1.2)	2 (0.7)	26 (1.7)	6 (4.9)		100 (1.0)
MCV (fl)	< 80	20 (1.2)	45 (1.5)	10 (1.5)	18 (2.1)	4 (0.8)	9 (1.4)	6 (1.2)	4 (1.0)	3 (1.1)	17 (1.1)	2 (1.6)		138 (1.4)
	> 100	2 (0.1)	3 (0.1)		2 (0.2)				1 (0.2)		8 (0.5)	1 (0.8)		17 (0.2)
Ly (×10⁹/L)	< 1.2	10 (0.6)	30 (1.0)	10 (1.5)	9 (1.0)	10 (2.1)	14 (2.2)	6 (1.2)	6 (1.5)	5 (1.9)	8 (0.5)	1 (0.8)		109 (1.1)
	> 3.5	146 (8.7)	185 (6.3)	63 (9.3)	85 (9.8)	47 (9.9)	69 (10.8)	63 (12.2)	44 (10.7)	38 (14.2)	134 (9.0)	12 (9.8)	10 (52.6)	896 (8.9)
Ne (×10⁹/L)	< 1.4	12 (0.7)	6 (0.2)		1 (0.1)	1 (0.2)	2 (0.3)	1 (0.2)		1 (0.4)	6 (0.4)			30 (0.3)
	> 6.6	56 (3.3)	156 (5.3)	30 (4.4)	49 (5.7)	26 (5.5)	29 (4.5)	37 (7.2)	25 (6.1)	15 (5.6)	153 (10.2)	18 (14.6)	2 (10.5)	596 (5.9)
Eo (×10⁹/L)	> 0.5	273 (16.3)	376 (12.8)	175 (25.8)	152 (17.5)	137 (29.0)	132 (20.7)	111 (21.5)	86 (21.0)	91 (34.1)	285 (19.1)	35 (28.5)	12 (63.2)	1865 (18.5)
Mo (×10⁹/L)	< 0.12	25 (1.5)	66 (2.3)	14 (2.1)	18 (2.1)	12 (2.5)	25 (3.9)	18 (3.5)	9 (2.2)	2 (0.7)	16 (1.1)			205 (2.0)
	> 1.00	39 (2.3)	25 (0.9)	9 (1.3)	13 (1.5)	11 (2.3)	7 (1.1)	8 (1.5)	7 (1.7)	4 (1.5)	20 (1.3)	9 (7.3)	1 (5.3)	153 (1.5)
Number of children measured		1673	2928	677	867	473	638	517	410	267	1496	123	19	10 088

[a] Parenthetic entries refer to the percentage of the subjects while empty spaces denote the absence of subjects with abnormalities.

[b] KOR, Korosten City; KRR, Korostenskii; LUG, Luginskii; OLE, Olevskii; MAL, Malinskii; EMI, Emilchinskii; OVR, Ovruchskii; NAR, Narodichskii; NVL, Novograd-Volinskii; VVL, Volodar-Volinskii; BRU, Brusilovskii; RAD, Radomishliskii.

[c] Hb, hemoglobin; WBC, white blood cell (leukocyte); PLT, platelet; MCV, mean corpuscular volume; Ly, lymphocyte; Ne, neutrophil; Eo, eosinophil; Mo, monocyte.

from 0 to 50 Bq/kg was the largest, and the highest level of deviations from normal range was registered in this group.

It should be noted that the highest number of anemia cases was registered in Volodar-Volinskii Rayon, where 19 of the 2,816 children examined were found to have anemia. Leukopenia was found more frequently in Korosten City (8 out of 3,156 children examined). The highest number of cases with thrombocytopenia was also found in Volodar-Volinskii Rayon (8 out of 2,816 examined children). A considerable number of children with thrombocytosis (40 subjects) was registered in the same rayon (Tables 6A and 6B).

Table 7 show the results of re-examination of hematological abnormalities found at the initial examination. Out of the 83 children found to have anemia at the first examination, 58 (69.9%) underwent re-examination: 15 (25.9%) showed normal blood parameters, 1 (1.7%) had microspherocytic anemia, 19 (32.8%) had iron deficiency anemia and 23 (39.7%) had anemia of unconfirmed cause. Similarly, 21 (65.6%) of the 29 children initially found to have leukopenia underwent re-examination: 16 (76.2%) showed normal blood parameters, while 5 (23.8%) still exhibited leukopenia. The initial examination revealed 15 children with thrombocytopenia (PLT $< 100 \times 10^9$/L), and 12 (80%) of these were re-examined: 3 children (25%) showed normal blood parameters, while 9 (33.3%) still exhibited thrombocytopenic purpura. Among the 387 (11.1%) of 3,485 children found to have eosinophilia at the first examination, 205 (53%) showed results within the normal range, while 182 (47%) still exhibited eosinophilia at re-examination. The initial examination revealed 188 children with thrombocytosis. Of the 75 children (40%) re-examined, 59 (78.7%)

Table 7. Results of re-examination of children found to have hematological abnormalities at the screening.

Blood analysis		Number of children with abnormalities at screening	Number of children undergoing re-examination	Results of re-examination
Item (unit)[a]	Abnormality criteria			
Hb (g/L)	< 110	83	58	15 - normal 1 - microspherocytic anemia 19 - iron deficiency anemia 23 - other anemia
WBC ($\times 10^9$/L)	< 3.8 for boys < 3.6 for girls	29	21	16 - normal 5 - leukopenia
PLT ($\times 10^9$/L)	< 100	15	12	3 - normal 9 - thrombocytopenia, 4 of these are Werlhof's disease
	> 440	188	75	59 - normal 16 - thrombocytosis
Eo ($\times 10^9$/L)	> 0.5	3485	387	205 - normal 182 - eosinophilia

[a] Hb, hemoglobin; WBC, white blood cell (leukocyte); PLT, platelet; Eo, eosinophil.

showed normal blood parameters, while 16 (21.3%) continued to show thrombocytosis.

One child was found to have acute lymphoblast leukemia (ALL) in November 1994. The boy was born in 1984 and lives in Korosten City. He is under the constant observation of hematologists and is periodically admitted to Zhitomir Regional Children's Hospital for a course of treatment. The child was examined 15 times at the Sasakawa Chernobyl Center, Korosten.

4. Conclusions

The results of the investigations show that abnormalities in the thyroid and peripheral blood continue to appear in recent years in most cases without obvious signs of disease. An increase in childhood thyroid cancer is noted year after year. It is important to continue these investigations and to carefully observe children exposed to the Chernobyl catastrophe.

II. Comments by Japanese Scientists

Comments on the 1995 Chernobyl Sasakawa Project Workshop on Thyroid-related Studies

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The fourth workshop was held on July 7 and 8, 1995 in St. Petersburg. The responsible persons and scientists in each field at the five centers gathered to discuss their manuscripts and data for the scheduled publication of a report in English and Russian and also to make preparations for the Gomel symposium on November 17 and 18, 1995. Since this was not only the fourth workshop but also the last fiscal year in which examinations are being conducted, the meeting was charged with anxiety about the future of the project and was closed to persons other than those directly involved. The person in charge of each center and five to ten scientists were invited, but the hospital director and scientist in charge of thyroid examinations from Gomel were absent. The hospital director from Kiev was also absent, but Dr. Natalia Nikifarova took general responsibility for the presentation. The hospital director from the Klincy Center took all the trouble to travel to St. Petersburg by bus but unfortunately was unable to attend the meeting and to participate in discussions.

As in past years, the checking of data on thyroid examinations and consideration of the reports from each center was conducted as follows. We looked at the findings of ultrasonographic examinations, the abnormalities in thyroid auto-antibody titers, the abnormalities in serum hormone (FT_4 and TSH) concentrations, and the results of echo-guided cytological examinations and then corrected the data and changed expressions where necessary. We also looked at the results of urinary iodine measurements. In all these categories we evaluated the results of analysis and looked at the correlation between irradiation and the Ci/km^2 not only in the current place of residence but also in the place of residence at the time of the accident. The examinations are already proceeding smoothly, and there been improvements in examination and diagnosis. The confident activities of the staff at each center and the excellent reputation in each region testify to the fact that the Chernobyl Sasakawa Health and Medical Cooperation Project has taken root.

As described in the WHO IPHECA, my impression of the current situation in the Chernobyl area is that medical organizations are struggling to deal with the dramatic increase in thyroid cancer among children. The improvements in the quality of examinations has led to increased attention concerning thyroid diseases and epidemiological investigations on the relationship between these diseases and radiation exposure by various organizations. How to provide post-surgical management, i.e. re-operation, radioisotope therapy and drug replacement, etc., and to prevent recurrence in children

Table 1. Number of childhood thyroid cancer discovered and operated surgically in 1986–1994 around the Chernobyl (Age at time of diagnosis 0–14 years).

	1986	1987	1988	1989	1990	1991	1992	1993	1994	Total
Belarus	2	4	5	7	29	59	66	79	83	333
Ukraine	8	7	8	11	26	22	47	42	37 *	208 *
Russia	6	1	0	0	2	0	4	5	11	23

* Incomplete number. Total population of children in Belarus, Ukraine and Russian Federation (Bryansk and Kaluga regions) is about 2,300,000, 12,000,000 and 500,000, respectively. These data were obtained at the WHO IPHECA Meeting in Obninsk in March 1995 and the complete report will be released to the public at the International Conference of Health Consequence of the Chernobyl and Other Radiological Accidents in November 20–23, 1995 (Geneva, Switzerland).

found to have cancer during screening are support categories that demand urgent attention, especially when medical treatment is in such dire straits. As shown in Table 1, the number of children undergoing surgery for thyroid cancer is increasing annually in all three countries (Belarus, Ukraine and Russia). This trend continues in 1995. The increase in thyroid cancer is also evident among adults. Interestingly, virtually no thyroid cancer has been found among children born after 1986, suggesting the necessity to conduct examinations for age groups other than those subject to the Sasakawa project heretofore (0 to 10 years old at the time of the accident, or 8 to 18 years old at present).

The contents of the reports from the five centers are summarized in Tables 2 to 4. A total of 109,558 children underwent screening at one of the five centers up to December 31, 1994 (Table 2). Cases with problems in coding or entering of data or with inappropriate examination results were excluded, leaving approximately 84,000 cases suitable for analysis this time. As a result of the steady improvement of quality management of the examination data, the present examination system for thyroid cancer in children is the best in the world in terms of both scale and content. I would like to express my heartfelt respect and gratitude to the directors and scientific staff of each center for their excellent work despite great political and economic difficulties.

Table 3 shows the incidence of thyroid disorders (goiter, nodule, abnormal echogenity) detected by ultrasonography at the five centers. We also investigated the frequency of thyroid dysfunction and positive auto-antibody titers by sex at each center. There was a close similarity with the results of the subjects examined up to December 31, 1993, but as expected the incidence of goiter tended to be high in the Kiev Center. Since it is difficult to draw a correlation between urinary iodine titers and goiter, we planned to conduct a comparison between the incidence of goiter by district in the Chernobyl vicinity and mean urinary iodine titers as a group. The

Table 2. Total number of children screened at the five centers.

Duration	Belarus		Russia	Ukraine		Total
	Mogilev	Gomel	Klincy	Kiev	Korosten	
1991.5–1994.12.31	21,242	21,642	24,832	20,780	21,062	109,558

Table 3. Incidence of childhood thyroid diseases at the five centers around the Chernobyl (%).

Thyroid disorders	Belarus		Russia	Ukraine	
	Mogilev	Gomel	Klincy	Kiev	Korosten
Goiter (range)	6–31	4–56	31–53	38–75	12–49
Nodule (s)	0.12 (0.08/0.15)	1.81 (1.30/2.28)	0.59 (0.56/0.63)	0.16 (0.12/0.19)	0.28 (0.17/0.37)
Abnormal echogenity	1.09 (0.54/1.59)	4.09 (2.97/5.13)	2.37 (1.99/2.75)	2.37 (–)	0.66 (0.20/1.06)
Hyperthyroidism	0.43 (0.36/0.49)	0.11 (0.06/0.16)	0.05 (0.02/0.08)	0.09 (0.06/0.11)	0.07 (0.02/0.12)
Hypothyroidism	0.07 (0.06/0.08)	0.28 (0.19/0.36)	0.09 (0.07/0.11)	0.04 (0.03/0.04)	0.13 (0.08/0.17)
Positive auto-antibodies					
ATG	1.1 (0.5/1.7)	0.9 (0.6/1.2)	1.2 (0.7/1.8)	1.2 (0.6/1.8)	3.1 (2.2/3.9)
AMC	1.9 (0.7/3/0)	2.4 (1.6/3.1)	1.8 (0.9/2.7)	2.1 (1.2/3.0)	3.5 (2.0/4.8)

The incidence of goiter, nodules and abnormal echogenity was analyzed by ultrasound images.
ATG: anti-thyroglobulin antibody, AMC: antimicrosome antibody, (/): (boy/girl), (–): data not analyzed.

incidence of thyroid nodule at the Klincy Center was second to only that at the Gomel Center. Interestingly, although the frequency of abnormal echogenity was high in Gomel and low in Korosten, positive auto-antibody titers were found in a high 3.1% and 3.5% of subjects in Korosten for ATG and AMC, respectively. Further investigation is needed to clarify these results. The incidence of thyroid dysfunction showed little variation among the centers (aside from the 0.43% frequency of hyperthyroidism in Mogilev), suggesting the existence of an approximately 0.1% incidence of asymptomatic thyroid dysfunction among the children. Of course, unlike the mass screening of neonates, no subjects with complications such as severe nervous disorders or classical myxedema have been found. Most of the cases are chemical hypothyroidism due to chronic thyroiditis and Grave's disease, and all of the patients are presently receiving appropriate treatment and follow-up. The problem is the lack of information about whether or not these patients are receiving proper management and administration of drugs under the current stringent medical circumstances. In view of these circumstances, the incidence of hyperthyroidism reported in Mogilev demands further explanation. Last summer, 50 cases of chemical thyrotoxicosis were discovered by the Mogilev Center during examinations at a certain sanatorium. When 43 of the 50 subjects were re-examined three months later, all had returned to a euthyroid state, and although there were three cases with positive auto-antibody titers, no obvious thyroid dysfunction was recognized. The samples were examined twice, but the results of the assay remained correct. Because the above 50 cases of hyperthyroidism found at the initial screening were included in the data, the incidence of hyperthyroidism seems to be high in Mogilev. When they are excluded, however, the incidence falls below 0.1% and is no different from that at the other centers. What, then, is the significance of the data in this group of children? The first possibility that comes to mind is oral administration of thyroid hormones, but this was denied by the physicians at the sanatorium and other persons. The second possibility is that thyroid hormones were contained in food eaten by the children. The occurrence of district-specific hyperthyroidism was reported among a group of people that ate hamburgers in a certain American town, and a questionnaire revealed that these people had eaten meat purchased from the same shop. In other words, thyroid tissue from cows had found its way into the hamburger. In the present case, the hyperthyroidism did not occur in only one district, only children showed abnormalities, and the vast majority of people eating the same meals at the sanatarium did not show any effects. These facts indicate that the abnormal group is different from the above hamburger group. Needless to say, if it had been possible to examine the scintigraphy and uptake of ^{131}I to the thyroid at the time, the exogenous hyperthyroidism would probably have been diagnosed correctly. This series of 50 cases points to the possibility that the vitamins, hormones and other medical supplies contained in emergency packages from abroad were administered inappropriately. There was already evidence of inappropriate medical treatment in the midst of the chaos and isolation after the Chernobyl accident. In particular, there were rumors that not only iodine but also thyroid hormones were administered in some districts as a way to prevent goiter. This possibility is still strongly evident. It is a problem that deserves attention, and awareness should be increased by whatever means. From the same viewpoint, it is necessary not to jump to the conclusion that the abnormally high incidence of thyroid cancer among children is caused by "radiation" but to investigate various other possible causes.

Table 4 shows the results of echo-guided fine needle aspiration biopsy (FNAB) performed on children selected by each center, mainly those with nodules of 5 mm or more in size and abnormal echogenity discovered by the present project. Although there is of course some sampling bias, the cytological results show benign lesions in most of the cases. Chronic thyroiditis, adenomatous goiter and cyst are particularly frequent. Still, the total of 14 cases of papillary carcinoma found in Gomel is an abnormally high number and deserves attention among the 20,000 cases that underwent examinations at the center over the past four years. The category "unclassified" includes cases that could not be diagnosed because insufficient cells or only normal follicular cells were obtained. This is a group that should be diagnosed and categorized in the future, but in particular the cases in which malignancy is suspected are scheduled to undergo comprehensive re-examinations as soon as possible. If the data

Table 4. Cytological diagnosis of childhood thyroid diseases performed under the echo-guided fine needle aspiration biopsy around the Chernobyl.

	Cases	Papillary carcinoma	Medullary carcinoma	Follicular neoplasm	Adenomatous goiter	Cyst	Chronic thyroiditis	Unclassified
Belarus								
Mogilev	33	1	0	1	7	9	6	9
Gomel	98	14	0	6	13	25	22	18
Russia								
Klincy	70	1	1	2	17	17	11	21
Ukraine								
Kiev	33	1	0	1	3	7	7	14
Korosten	140	3	0	13	20	23	40	41
Total	374	20	1	23	60	81	86	103
(%)	(100)	(5.3)	(0.3)	(6.2)	(16.0)	(21.7)	(23.0)	(27.5)

prior to the introduction of FNAB in the present project are included, there have been a total of 31 cases of thyroid cancer in children, consisting of 2, 21, 3, 5 and 4 cases in Mogilev, Gomel, Klincy, Kiev and Korosten, respectively. Except for one case of medullary carcinoma, all the cases were papillary carcinoma. Moreover, all of the cases have undergone surgery and follow-up examinations at affiliated institutions or hospitals, and we (specialists) have also examined the children and offered advise on treatment during our visits to the centers. Cytological examinations have been established now in the departments of pathology at the Mogilev and Gomel Centers, facilitating active and accurate diagnoses. At the Gomel Center, nine new cases of thyroid cancer have been diagnosed since the beginning of 1995 and all have undergone surgery at the Minsk Thyroid Cancer Center. With the agreement of Prof. Demidchik, we have discussed and confirmed the histological diagnoses and surgical findings of these cases during each of our trips to Minsk. We have completed a study on the results up to the end of December 1994 and have submitted this for publication in a scientific journal. Pediatrician Dr. Galina Panasuk and cytologist Dr. Larisa Kotova have both been to Nagasaki for training and are now leaders in the thyroid field at the Gomel Center. The scientists at the other centers who visited Nagasaki for training have also gained excellent skills in ultrasonography and other diagnostic techniques and are now contributing greatly to routine diagnostic activities.

Automatic analyzers for urinary iodine are now in use at the Mogilev and Kiev Centers. Thus all of the centers are conducting measurements smoothly and producing data. The reports from each center have not shown any correlation between urinary iodine titer and goiter, TSH or FT_4, etc., at least at the individual level. As the symposium approaches, we are planning to look for possible correlations by district and group.

With regard to the correlation between radiation dose and each thyroid abnormality, we investigated as in past years the ^{137}Cs levels (Bq/kg) in the body and the ^{137}Cs concentration (Ci/km^2) in the soil at the current place of residence but concluded that there is no correlation at least with the ^{137}Cs levels. We also added for the first time an investigation based on the codified places of residence at the time of the accident. There seem to be certain trends, but the results differ among centers and therefore require further study. It is particularly necessary to analyze the correlations with ^{131}I thyroid dose and ^{131}I concentrations in the soil, etc.

The above information was provided through analyses by the department of statistics at the Mogilev Center of the pooled thyroid diagnostic data from each center. Along with thanks to Dr. Shibata and the Mogilev staff for their analyses, I would like to express my admiration for the tremendous efforts made by each center. The following is an outline of the characteristic thyroid studies at each center.

1) The Mogilev Center is a hub for medical examinations in the oblast. Since its general examination system for adults is excellent, the center can provide follow-up examinations for the children as they grow, not only in the thyroid but in all other fields as well. The center is disadvantaged in that it has not been provided

with an Aloka 630 and has to share ultrasonography equipment for thyroid examinations, but FNAB is possible and the center has firmly established pathology and cytology departments. These provide well organized control data and thus play an important role in comparative studies. There is nothing lacking with regard to diagnoses or the attitude of the staff, but the most characteristic feature of the center is the fact that it is capable of analyzing data. Dosimetry and urinary iodine measurements are also established here, and we expect the Mogilev Center to play a comprehensive, leading role among the centers. A similar level of cooperation and scientific exchange with Japan can be expected to continue into the future.

2) As mentioned above, the Gomel Center is the object of global medical attention because it is the site of an extremely high incidence of thyroid cancer and nodules among children. In both a negative and positive sense, the effects of the Chernobyl accident on the human body cannot be discussed without reference to Gomel. This necessitates a firm, well organized future perspective. The center boasts excellent quality in thyroid cytology, and through exchanges with institutions such as the Minsk Thyroid Cancer Center and the department of pathology at Minsk Medical University it can become a hub for thyroid cancer research. It is of vital importance now to establish the most efficient possible operating system and to provide long-term follow-up examinations for the many cancer patients.

3) The Klincy Center does not have any powerful supporters; it has been the unparalleled efforts of the staff that have brought the center up to its present level. The aggressive approach adopted by Dr. Elena Karevskaya and her colleagues has spread to the physicians and other staff members. The three who underwent training in Nagasaki are now working diligently. With financial support, the center will be able to establish relationships of cooperation with institutions such as the Bryansk Regional Diagnostic Center and the Novozybkov Branch Institute of Radiation Medicine. Of particular importance is the continuation of thyroid ultrasonographic examinations in the highly contaminated areas of western Bryansk. Ongoing advice and support from Japan are very much needed.

4) The Kiev Center was established as an examination department in the Kiev State No.2 Hospital, and examinations are being conducted in the southern part of Kiev Oblast under the leadership of hospital director Dr. Elagin and physician Dr. Natalia Nikifarova. Since this is an iodine deficient area with a high incidence of goiter, the examinations are very important. From the beginning, however, the activities of a large number of affiliated institutions have overlapped, and thus there are difficulties, political and otherwise, in limiting studies and treatment to children of the Chernobyl area. The center is nevertheless fully capable of continuing its examination activities independently, and the re-evaluation of data such as subject selection will be needed. The reorganization of a unique examination system is possible, and the continuation of exchange with supporting hospi-

tals, etc. can be expected.

5) The Korosten Center constructed a new children's diagnostic clinic, using "Sasakawa Memorial Health Foundation" in the name, and is now engaged actively in thyroid examinations. The center greeted its fifth anniversary on July 25, 1995. Despite the election of a new mayor in the city of 70,000, the center has received uninterrupted support and has grown into a vital examination center in the northern part of the oblast, partly with the cooperation of the Zhitomir Regional Health Bureau. In the midst of dire financial straits in both the oblast and city, the imaging diagnosis of the thyroid and measurement of thyroid auto-antibody titers in the blood has been a great benefit to the local residents. Particularly noteworthy is the center's diagnostic accuracy and treatment of thyroiditis. The center promises to become an excellent clinical and diagnostic institution, but, like the Klincy Center, its greatest problem at hand is how to procure funding.

As described above, the contents of the reports from each center were considered comprehensively and, along with the reports on dosimetry and hematology, will be prepared for the fourth symposium at Gomel. The representatives from Gomel, Korosten and Kiev will be responsible for presentations on thyroid cancer and nodules in children, abnormal echogenity and positive auto-antibody titers, and goiter and urinary iodine, respectively. In view of the situation in each country and other circumstances, it is likely that differences will arise in the role and activities of each center and that it will no longer be possible to discuss our advice and support at a uniform level. It is undoubtedly important to promote relationships of cooperation based on the unique features of each center. Table 5 outlines the features of each center in the thyroid field. The centers have to recognize the importance of present workshops and the coming fourth symposium in Gomel and to think about the direction of their activities after the five-year project comes to an end. Along with the need for "emergency measures," the main characteristic of radiation injury is "late effects," that is, the vital importance of a long-term approach. The present project, which began as a humanitarian endeavor, is now winding to a close. Without a doubt, the project helped to improve the level of medical treatment for residents and to educate scientific

Table 5. Characteristics of the five centers at the standpoint of thyroid screening.

	Belarus		Russia	Ukraine	
	Mogilev	Gomel	Klincy	Kiev	Korosten
Disease characteristics	control areas	thyroid nodules thyroid cancers	abnormal echogenity	goiter iodine deficiency	positive ATG, AMC
Center capability	data analysis	cytological diagnosis	echo screening	iodine measurement	clinical diagnosis
Future demand	collaboration	organization efficiency	continuous support	collaboration	continuous support

personnel. Although there was some trial and error during the four-year period, the examination activities have generally proceeded very smoothly, a comment that I think applies not only to the thyroid but to other fields as well. In order to utilize the wealth of examination data on some 100,000 people, the continuation of long-term cohort studies, etc. is necessary, and I hope there will be efforts to prevent the scattering of data and to ensure the effective use of the data. The specialists including myself also hope to be able to assist in the future work of the centers in some way.

It is our ongoing hope to provide an environment in which the mothers and children of Chernobyl can live with peace of mind and to fulfill the mission of medicine by promoting the mental and physical health of local residents.

Comments on the Hematology Workshop

Kingo Fujimura and Takeshi Shimomura

Research Institute for Radiation Biology and Medicine
Hiroshima University

Generally speaking, the examination results of the five centers showed trends similar to those in the past. In addition to an overall view of the reports from the five centers, We will comment here on the ferritin measurements that were conducted for the first time and on the results of re-examinations.

Table 1 shows the total number of examinations at the five centers. No matter how high the quality of the equipment for diagnosis of blood diseases, the correct macroscopic observation of blood smears is essential for the supplementation and confirmation of the data coming out of the machine. Presently, all five centers have achieved that ability, and blood screening now has a high level of reliability.

Changes in hematological data by age

Although there has been a slight variation among the centers in hemoglobin concentration in the past, the difference becomes more conspicuous, particularly between boys and girls, in association with the emergence of the secondary sex character. In other words, there is a marked increase among boys, but the increase is mild among girls and in fact turns into a slight decrease after the age of 16 (Figure 1). Figure 2 shows the results of ferritin measurements by age and sex in the 571 subjects with no hematological disorders from the five centers. On the whole, the ferritin level reaches a peak around the age of ten and then gradually decreases with age. This trend is particularly strong in girls, indicating that the decrease in hemoglobin concentration is due to a latent iron deficiency. The fact that the thrombocyte count among girls is greater than that among boys from the age of 15 (Figure 3) may also reflect this iron

Table 1. Number of children receiving hematological examinations at the five centers from 1991 to 1994.

Center (Region)	Number of children examined
Mogilev (Mogilev Oblast)	17,550
Gomel (Gomel Oblast)	13,729
Klincy (Bryansk Oblast)	17,205
Kiev (Kiev Oblast)	18,700
Korosten (Zhitomir Oblast)	18,775
Total	85,959

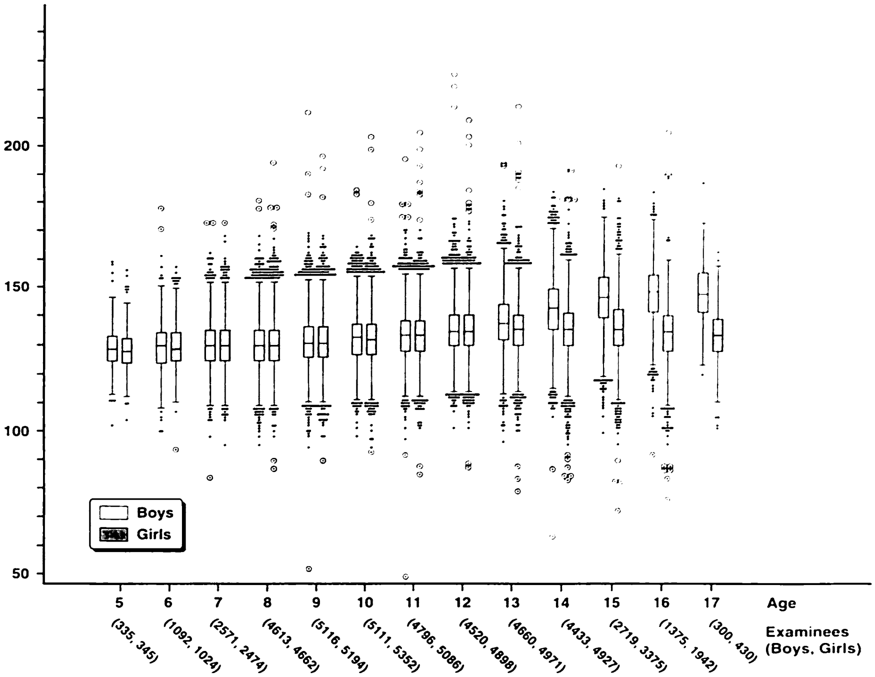


Figure 1. The box-and-whisker plots of hemoglobin level by sex and age among children examined at the five centers from 1991 to 1994.

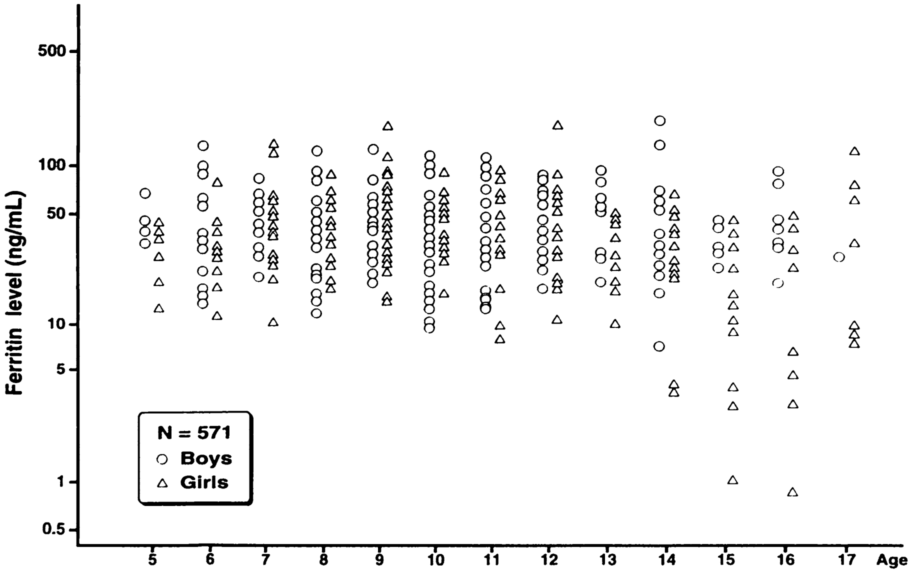


Figure 2. Distribution of ferritin level by age and sex in hematologically normal children examined at the five centers.

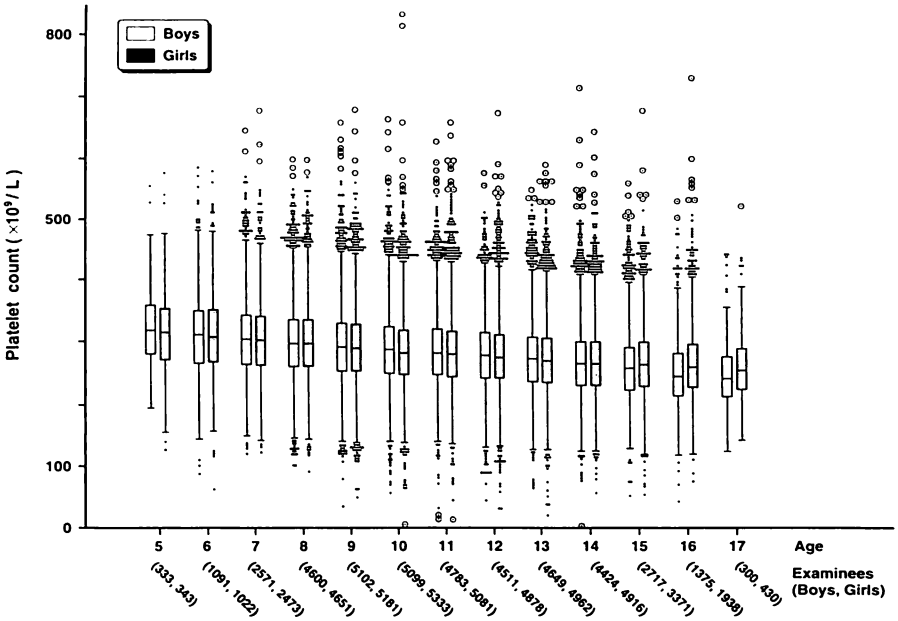


Figure 3. The box-and-whisker plots of platelet count by sex and age among children examined at the five centers from 1991 to 1994.

deficiency. Moreover, MCV levels are higher among girls than among boys at all ages, and a positive correlation is recognized between Hb and ferritin levels among anemia cases in which hemoglobin is 110 g/L or lower (Figure 4).

The leukocyte count shows a two-directional curve, decreasing from the age of five and then once again increasing from the age of 12 (Figure 5). This may be an expression of the fact that the lymphocyte count decreases from the age of five (Figure 6) and that the neutrophil count increases from the age of 12 (Figure 7). The increase in neutrophils physiologically is particularly evident among girls in addition to the reactive increase in thrombocytes due to iron deficiency from the age of 12, indicating the acceleration of hematopoiesis. In addition to reactive factors such as hematopoiesis, this suggests the involvement of hematopoietic factors due to the change in the endocrine environment and points to the need for future analyses of the changes in these hematopoietic factors.

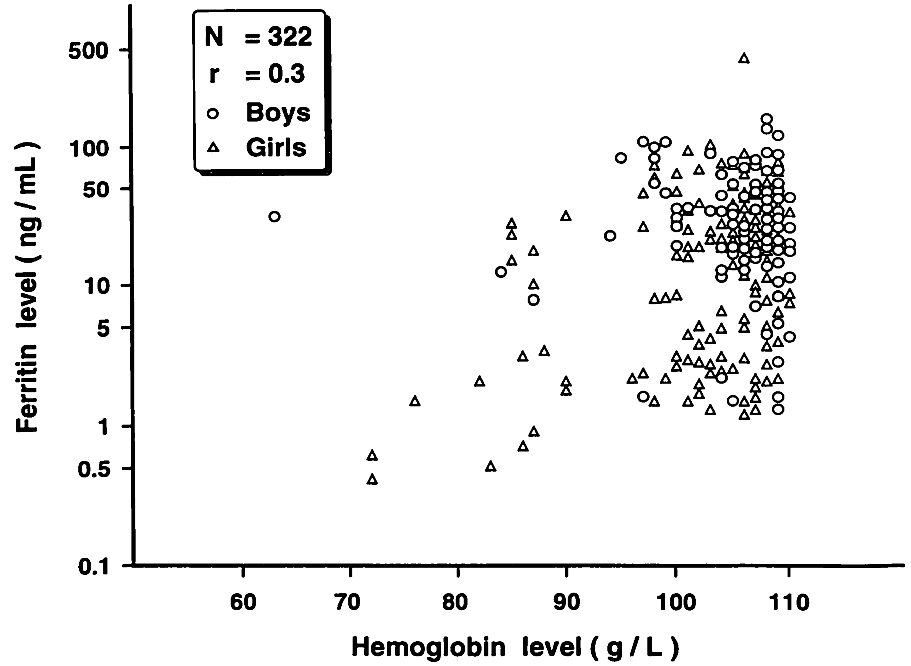


Figure 4. Scatter plots of hemoglobin (Hb) and ferritin levels among children examined at the five centers having Hb less than 110 g/L.

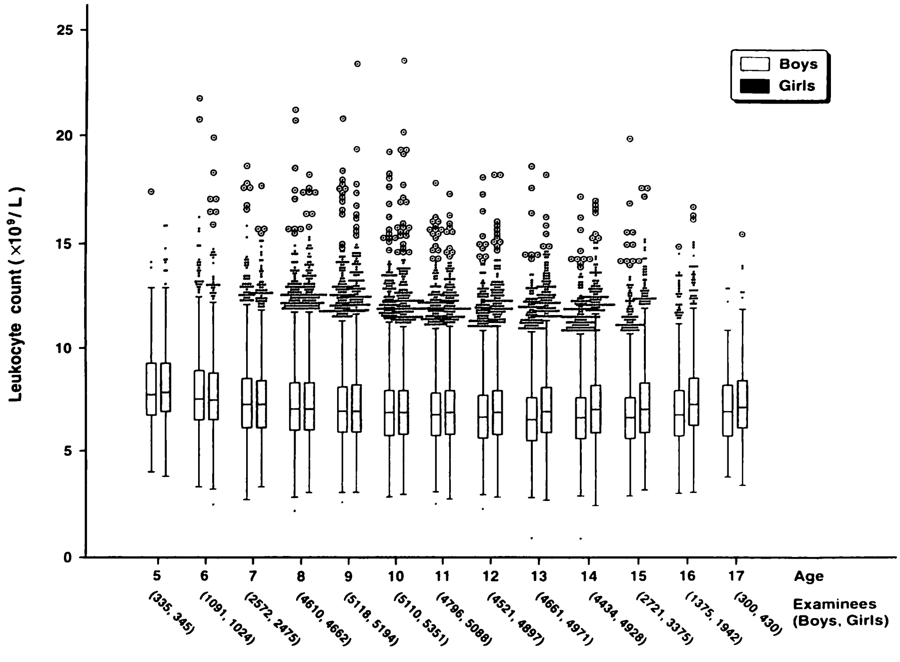


Figure 5. The box-and-whisker plots of leukocyte count by sex and age among children examined at the five centers from 1991 to 1994.

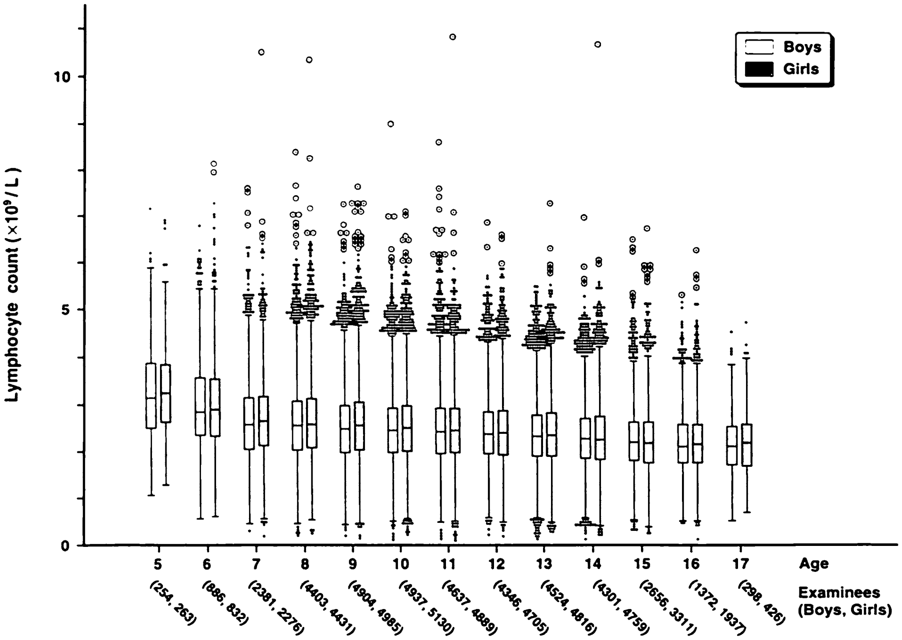


Figure 6. The box-and-whisker plots of lymphocyte count by sex and age among children examined at the five centers from 1991 to 1994.

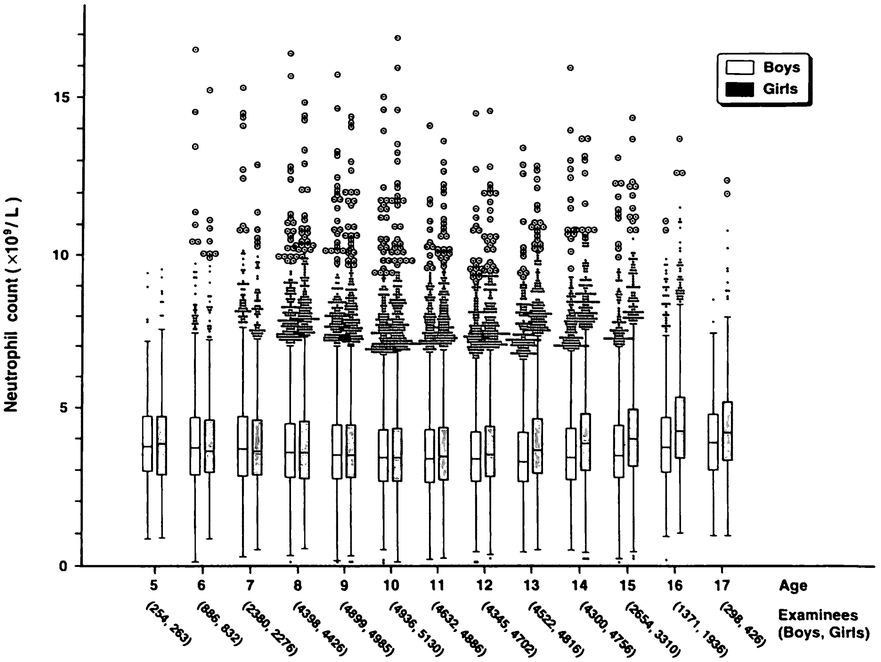


Figure 7. The box-and-whisker plots of neutrophil count by sex and age among children examined at the five centers from 1991 to 1994.

Hematological abnormalities and their causes

Table 2 presents an outline of the frequency of the most common hematological abnormalities found at the five centers. Eosinophilia was the most frequently encountered abnormality (about 13% to 19%), but a questionnaire survey revealed a positive correlation between this abnormality and the presence of domestic animals. This finding is further supported by the fact that the eosinophilia was 13% to 14% in the urban areas of Mogilev, Kiev and Gomel but 18% to 19% in Klincy and Korosten which are close to agricultural districts. Keeping allergic diseases of the respiratory system in mind, we are planning to analyze the seasonal changes in neutrophil count in individual subjects. Moreover, continuing attention must be paid to the fact that, in some areas, there is a positive statistical correlation between absolute eosinophil count and thrombocyte, monocyte and lymphocyte counts.

Although there is some variation in the rate of re-examination due to regional circumstances, 30% to 80% of the subjects with abnormal findings were re-examined at the five centers. On average, more than half of the subjects showed normal hematological findings on re-examination. The leukopenia and thrombocytopenia showed a particularly high rate of recovery (70% to 90%), indicating the possibility that these abnormalities had reflected the effects of physiological changes or viral

Table 2. Hematological abnormalities by center and sex in children found in the period from 1991 to 1994.[a]

Diagnosis	Center														
	Mogilev (17,550)			Gomel (13,729/10,453)			Klincy (17,205)			Kiev (18,700)			Korosten (18,775)		
	B	G	%	B	G	%	B	G	%	B	G	%	B	G	%
Anemia Hb < 110 g/L	10	21	0.2	32	41	0.5	14	28	0.2	44	67	0.6	29	54	0.4
Leukopenia B: WBC < 3.8 × 10^9/L G: WBC < 3.6 × 10^9/L	58	33	0.5	48	16	0.5	56	28	0.5	56	27	0.4	24	7	0.2
Leukocytosis B: WBC > 10.6 × 10^9/L G: WBC > 11.0 × 10^9/L	309	223	3.0	301	236	3.9	256	226	2.8	402	462	4.6	344	312	3.5
Thrombocytopenia PLT < 100 × 10^9/L	5	14	0.11	3	2	0.04	9	4	0.08	5	9	0.07	8	7	0.08
Thrombocytosis PLT > 440 × 10^9/L	136	146	1.6	106	96	1.5	89	73	0.9	163	161	1.7	88	100	1.0
Eosinophilia Eo > 0.5 × 10^9/L	1274	1156	13.8	692	704	13.4	1745	1638	19.7	1270	1367	14.1	1620	1865	18.6

[a] Figures in parentheses are the number of children examined. In Gomel, eosinophil was assayed in 10,435 children. B: boys, G: girls, %: percentage of children (boys and girls) with the respective abnormalities.

infections common in children. One exception was Korosten, where the cases of thrombocytopenia showed a recovery rate of only 16.7% at re-examination. The reasons for this are unclear; further studies on the cause of thrombocytopenia are necessary. Slightly less than 10% of the cases of thrombocytopenia undergoing re-examination showed disorders such as idiopathic thrombocytopenic purpura. The recovery rate in subjects with low hemoglobin levels was 20% to 70%. These included cases receiving iron preparations or other forms of treatment. Detailed examinations revealed that, among subjects with anemia at re-examination, iron deficiency anemia was the most common abnormality and accounted for 74.4% of cases. This is probably due either to the state of nutrition or to problems in medical treatment. It is necessary to look at the questionnaire results in conjunction with the above findings. It is also necessary to focus attention on the fact that iron deficiency anemia was found in 64% and 44% of subjects in Gomel and Kiev, respectively, at re-examination, but it should be noted that no correlation was recognized between these abnormalities and age, place of residence or radiation dose. Although the influence of measurement error should of course be considered with regard to the high recovery rate of numerical abnormalities, it is often difficult to prove the existence of such error. We think we can assume that most of these abnormalities are transitory because each blood sample is re-examined and confirmed on the day of collection, at least when the stirring of the sample was insufficient or there was some problem with the equipment. The results of re-examination are extremely important for the reliability of the hematological studies. It is essential, therefore, to keep medical records on matters such as the period between examination and re-examination and the reasons for recovery or continuing abnormalities.

The relationship between radiocontamination and the frequency of hematological abnormalities

No significant correlation has been recognized between ^{137}Cs dose in the body and the frequency of hematological abnormalities. But although no correlation has been found overall between the level of radiocontamination in the place of residence at the time of the accident and the frequency of abnormalities, there is a positive correlation between the radiocontamination and the abnormal frequency of low MCV level and thrombocytosis in Klincy and Mogilev, respectively. In the highly contaminated Gordeevskii district of Klincy, a low MCV level was observed in 31.3% of boys and 19.8% of girls. In view of the fact that the frequency of anemia (0.8% and 0.5%, respectively) and other abnormalities in this district showed no difference with that in other districts, it is necessary to investigate the abnormal frequency of low MCV level by conducting re-examinations and clarifying other factors such as the presence of latent iron deficiency.

To date, a total of four cases of hematological malignancy (acute leukemia, malignant lymphoma, etc.) have been encountered at the five centers, including cases diagnosed by screening and those undergoing treatment at other institutions (one case of ALL in Korosten; one case of AML in Klincy; two cases of ALL [L_1, pre B-cell type] in Gomel). None of these subjects are residents of highly contaminated districts, nor did any show a high ^{137}Cs dose in the body.

Problems

Problems in the examinations for hematological diseases include the fact 1) that severe abnormalities tend to take an acute clinical course and to pass detection by the current screening system and 2) that the blood examinations in the medical centers are by nature only screening and do not include confirmative diagnoses by supplementary investigations or blood marrow tests, etc., making it necessary to rely on the personal efforts of the responsible staff for the collection of data on the final diagnosis of abnormalities. What is called for, therefore, is the organization of an information exchange system with medical institutions in each district and the supplementation thereby of data for analysis. In any case, it is extremely significant that a screening system was established relatively soon after the Chernobyl accident and data on some 100,000 subjects has been accumulated for analysis. From the epidemiological standpoint, it is necessary now to conduct follow-up studies on these subjects to determine whether or not radiation exposure causes hematological abnormalities.

Comments on the Chernobyl Sasakawa Medical Cooperation Workshop

Masaharu Hoshi

Research Institute for Radiation Biology and Medicine
Hiroshima University

1. Introduction

The 4th workshop was held on July 7 and 8, 1995 in St. Petersburg to discuss verbally the methods of presentation and conclusion of reports for the 4th symposium scheduled for November 17 and 18 this year. One feature of this year was the decision to arrange the results separately for each field of study.

2. Sub-meeting on dosimetry

2-1. A sub-meeting on dosimetry was convened after the plenary session. Dr. Okajima was one of the participants this year. The presentation was made by the Mogilev Center. As in past years, the data was shown by age and village of residence using box-and-whisker plots. Dr. Okajima pointed out that only old data may be contained at ages five and six because examinations were launched on the condition that the children were 0 to 10 years of age at the time of the accident. Contamination levels are higher in the older data and decrease over time. Since it is probably inappropriate to look at age differences, therefore, we excluded the children at ages five and six.

Otherwise there was no particular problem. The trends evident in the graphs were similar to those of past years: 1) There was no difference by age, although girls of high ages tended to have lower cesium levels than boys. It is not possible to draw a conclusion from this data alone, the tendency may be related to the fact that boys become muscular with age while girls gain more fat, because cesium enters muscle tissue more easily than fat tissue. 2) There were villages with high cesium levels only in Gomel. Some had levels over 100 Bq/kg. This finding probably reflects the fact that contamination was highest in Gomel and that there are large differences in the contamination among districts.

2-2. Also, this time we participated in the international mutual comparison of dosimeters and, for that purpose, brought the phantom that had been sent to Japan from Canada. The Klincy Center measurements were conducted using this phantom. The result was excellent, with a ratio of 1.126 between the measured levels and the actual level of ^{137}Cs in the phantom. This means that the measured levels were 12.6% higher than the phantom level. This will be reported as a letter to the editor in the international journal "Health Physics."

2-3. Dr. Masyakin from the Gomel Center brought a report on the relationship between thyroid dose and abnormalities. He had obtained data on the dose reconstruction of iodine. On the basis of this, he entered information on movements and other individual data and calculated individual doses. From this information he analyzed the relationship between thyroid dose and abnormalities. The results seemed to show a correlation between thyroid nodules and reconstructed iodine dose. There was no correlation, however, with levels of cesium contamination.

3. Conclusion

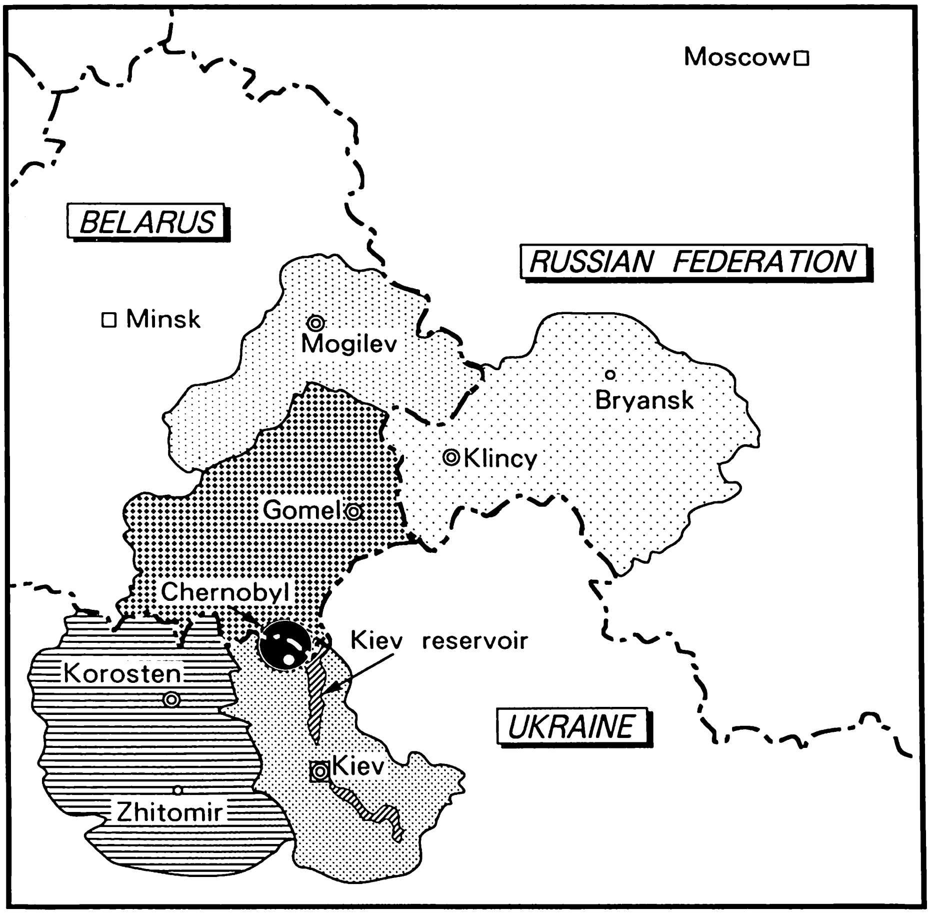
The workshop ended successfully. The presentation of reports according to each field of study will make it easier for the listeners to understand.

Aside from its examination activities, the dosimetry group is conducting research on the estimation of contamination in the soil and exterior radiation dose, mainly at the Mogilev Center. The results will be reported when available.

III. Appendix

Appendix A

Location of the Five Centers



Map showing the five oblasts. The locations of the five centers are shown with double circles.

Appendix B

Directory of Five Centers and Coordinating Office

Republic of Belarus

Gomel Specialized Medical Dispensary
Bratyev Lizyukovich 5, Gomel, Belarus 246029
Head Doctor: Dr. Viktor E. Derzhitsky
Tel: 375–232–48–7120 Fax: 375–232–53–1903

Mogilev Regional Medical Diagnostic Center
Pervomayskaya 59, Mogilev, Belarus 212030
Head Doctor: Dr. Tadeush A. Krupnik
Tel: 375–222–22–4745 Fax: 375–222–22–2997

Russian Federation

Klincy City Children's Hospital
Sverdlovskaya 76, Klincy, Bryansk Area, Russian Federation 243100
Head Doctor: Dr. Alexey A. Averichev
Tel: 7–08336–2–0454 Fax: 7–08336–2–2411

Ukraine

Kiev Regional Hospital No. 2
Nesterovsky per 13/19, Kiev, Ukraine 253053
Head Doctor: Dr. Vladimir V. Elagin
Tel: 380–44–225–5025 Fax: 380–44–212–3412

Korosten Inter-Area Medical Diagnostic Center
Kievskaya 21b, Korosten, Zhitomir Area, Ukraine 260100
Head Doctor: Dr. Valeriy V. Danilyuk
Tel: 380–4142–3–2001 Fax: 380–4142–3–0459

Coordinating Office

Moscow Office of Sasakawa Memorial Health Foundation
117049 Mytnaya Street 1, Moscow, Russian Federation
Manager: Mr. Mikhail B. Bondarenko
Tel: 7–095–943–9479/9579 Fax: 7–501–943–9350

Appendix C

Major Activities of the Chernobyl Sasakawa Health and Medical Cooperation Project: 1991–1994

Date	Event
Early 1990	A request is received from the former USSR to Sasakawa Memorial Health Foundation for direct humanitarian assistance
August	A group of Japanese scientists headed by Mr. Y. Sasakawa visits Chernobyl and the related areas and medical institutions.
November	Japanese specialists visit the then All Union Scientific Center of Radiation Medicine in Kiev
26 April 1991	Five mobile diagnostic buses are donated
May	The project staff of the five centers receives training at Obninsk.
May-July	Japanese scientists and staff visit and stay at the five centers
September	The project staff of the five centers receives training in Hiroshima and Nagasaki
October	Working group conference is held in Moscow
December	Japanese staff visits the five centers
January 1992	Japanese scientists visit the five centers The Memorandum of Understanding between the Foundation and five centers is signed in Moscow
June	The First Chernobyl Sasakawa Medical Symposium is held in Mogilev Japanese scientists visit the five centers
November	Japanese scientists visit the five centers
January-February 1993	Japanese scientists visit the five centers
April	The First Workshop is held in Moscow The project staff of the five centers receives training in Hyogo
June-July	Japanese scientists visit the five centers The Second Workshop is held in Moscow
October	The Second Chernobyl Sasakawa Medical Symposium is held in Korosten Japanese scientists visit the five centers
January 1994	Japanese scientists visit the five centers

March	Japanese scientists visit the five centers
May	Japanese scientists visit the five centers
June	Japanese scientists visit the five centers
July-August	The project staff of the five centers receives training in Hiroshima and Nagasaki
September	The Third Chernobyl Sasakawa Medical Symposium is held in Bryansk
	Japanese scientists visit the five centers
December	The project staff of the five centers receives training in Hiroshima

POSTSCRIPT

A Chernobyl Sasakawa Health and Medical Cooperation Project workshop has been conducted every year since 1992 to assess the data including that accumulated over the past year. Reports on three workshops have been published thus far, which makes the present report the fourth in the series. As of December 31, 1994, a total of 109,558 individuals have undergone examinations, and the centers have reported on approximately 84,000 individuals with analyzed data.

The fourth workshop was held in St. Petersburg on July 7 and 8, 1995. As in the past, the reports in English and Russian were prepared through the efforts of the computer section at Mogilev Center, and discussions were held separately in the three fields (thyroid, hematology and dosimetry). The problems faced in each field are summarized in the comments included in this report, but the specialists praise the efforts and achievements of the centers in the face of stringent social and economic conditions. The quality control of the examination data and information on individuals has indeed improved yearly, and the data accumulated to date provides an invaluable database for future analyses. The other accumulated materials such as blood smears, serum samples, thyroid images preserved on magneto-optical disks and information on ^{137}Cs dose in the body will also play a vital role in both retrospective and prospective studies.

The original aim of the project, namely humanitarian assistance to children and other inhabitants of the contaminated regions, has gradually branched out into the realm of scientific analysis. The local medical staffs, health bureaus and health departments are also searching for ways to make efficient use of each center and examination bus within the limits of the allotted budget. Next year we greet the 10th anniversary of the Chernobyl accident. It is necessary to proceed with studies that will provide answers, not only about acute radiation-induced disorders, but about the problem of how to lead a stable life in the midst of the worst radio-contamination in the history of humankind. Keen attention is also focused on the need for meticulous follow-up studies, early diagnoses and prompt treatment for individuals in the high-risk groups.

Along with thanks to the various persons who provided assistance in the publication of this report on such a tight schedule, we express our hopes that the report will be widely read and that it will serve as a source of accurate information for the residents of the Chernobyl area.

In conclusion we offer prayers for the repose of the soul of the late Ryoichi Sasakawa, the father of the present project.

The Editors
Shunichi Yamashita
Kingo Fujimura
Masaharu Hoshi
Yoshisada Shibata

October 1995

CHERNOBYL SASAKAWA HEALTH AND MEDICAL COOPERATION PROJECT