Evaluation of the Current Radiation Burden of Children Living in Regions Contaminated by the Chernobyl Accident

P. Hill¹, M. Schläger¹, H. Dederichs¹, R. Lennartz¹, R. Hille¹, V. I. Babenko², A. V. Nesterenko², V. B. Nesterenko²

¹Forschungszentrum Jülich GmbH, Geschäftsbereich S, D-52425 Jülich, Germany
E-mail: ass.info@fz-juelich.de

²Belarusian Institute of Radiation Safety (BELRAD), Charity House, 11 Staroborisovsky Trakt, BY-220114 Minsk, Belarus
E-mail: nester@hmti.ac.by

Abstract. About 18 years after the Chernobyl accident, the verification and documentation of the long-term development of radiation doses is still required, especially in environments where ingestion considerably contributes to the current and future dose commitment of the population.

A population group of special concern are the children living in the contaminated regions. Out of the two million Belarusian children, approximately 80000 children live in regions contaminated after the Chernobyl accident by a Cs-137 deposition of more than 185 kBq/m². A German-Belarusian project funded by the German Federal Office for Radiation Protection is presently investigating radiation burdens of children in those regions.

Whole-body counting results have been obtained for close to 17000 children using seven transportable in-vivo monitors. The measurements were mostly done in schools or kindergartens situated in the contaminated regions. Mean internal doses were calculated for the total group of children measured in a settlement as well as for the critical group, which was defined as the ten most highly exposed children. To compare results with the international dose limit of 1 mSv/a an external dose contribution was added based on the amount of the original Cs-deposition at the corresponding settlement.

Though even for the critical group total annual doses were generally below 1 mSv/a in some cases this limit was exceeded, essentially due to high ingestion doses. The authors are deeply convinced that nearly 20 years after the Chernobyl accident doses above the international dose limit of 1 mSv/a are no longer acceptable by ethic reasons, especially not for children. Therefore, honest efforts must be performed to reach this goal.

1. Introduction

After the Chernobyl reactor accident wide areas of Belarus (e.g. Gomel region) have been contaminated with radioactive fallout. Up to now the consequence is a chronic intake of radionuclides by ingestion, especially if uncontaminated foodstuffs from other regions are not available. About 18 years after the Chernobyl accident, the majority of the adult people living in the contaminated regions of Belarus have already received the essential portion of their total long-term dose commitment. However, exceptions from this general observation exist. As a general rule, the verification and documentation of the long-term development of radiation doses is still required, especially in environments where ingestion considerably contributes to the current and future dose commitment of the population. Such a situation can be found in settlements in forestial regions e.g. in the Gomel district east of Korma [1].

A population group of special concern are the children living in contaminated regions. Out of the two million Belarusian children, approximately 80000 children live in regions contaminated after the Chernobyl accident by a Cs-137 deposition of more than 185 kBq/m². A German-Belarusian project funded by the German Federal Office for Radiation Protection (BfS) is presently investigating radiation burdens of children in those regions. Project partners are the Belarusian Institute of radiation Safety (BELRAD), Minsk, and the German Research Centre Jülich GmbH (FZJ), Jülich. A main objective of the project is the identification of areas, where children are at risk to receive radiation doses higher than the international level of 1 mSv/a; for this purpose whole-body counter measurements of the ‘key nuclide’ Cs-137 are carried out to determine the children’s body burdens. In
a later phase of the project highly contaminated settlements will be selected for further investigations including up to 5000 children. Then the aim will be to examine whether internal doses which are still above 1 mSv/a can be reduced by radiation protection and decorporation measures.

2. Study design

The research project consists of three parts. In Part I a joint data base is created, which includes all data already available either at the research centre Jülich or at BELRAD from previous measurements. This involves e.g. data of the German Chernobyl Project 1991-1993 [2,3] and data gathered by BELRAD from 1996 to March 2002. Those data will be evaluated in order to identify settlements with potentially enhanced radiation burdens of the population.

Based on the data evaluation of phase I serial measurements of the Cs body-burden are performed during part II at those settlements selected for further evaluation. This will result in more current data for about 17000 children to evaluate the actual situation. Field measurements will be performed using the seven portable whole-body counters of BELRAD and mobile whole-body counters of the Research Centre Jülich. The main criterion for selection of the settlements is an effective dose of the critical group of at least 0.3 mSv/a, the critical group being defined as the 10 most highly exposed children of a given settlement.

The serial measurements of project part II shall provide updated exposure information, which will be used to select up to 5000 children for further investigation in part III of the project. They shall contribute to the evaluation of possible measures to be taken in addition to the control of radioactivity content of nutrition in order to further reduce the annual effective dose of children in the contaminated regions of Belarus. Special attention will be given to the cure-like application of pectin preparations, which are claimed by Belarusian scientists to show a dose-lowering effect by reducing the Cs body burden.

3. Methods

The great majority of the measurements of children have been carried out by BELRAD with seven portable chair-type in-vivo monitors (SCRINNER-3M), each containing a sodium iodide detector. The measurements usually take place in schools and kindergartens situated in highly contaminated regions of Belarus. Figure 1 shows a SCRINNER-3M instrument with peripheral equipment during the examination of a Belarusian child.

The Research Centre Jülich contributes three mobile whole-body counters (WBC) to the project: A commercially available Fastscan system (Canberra Industries) and two bed-type WBCs which have been developed and built at the FZJ. Each of these devices contains two large sodium iodide detectors. The German whole-body counters are mainly used in joint Belarusian-German comparison measurements with phantoms (intercalibration) and children (intervalidation) which are performed as an important part of the quality assurance program.

In the period between April 2002 and November 2003 four intercomparison campaigns took place in Belarus. For intercalibration measurements the 12 kg, 24 kg, 50 kg and 70 kg versions of a St Petersburg brick phantom [4] filled with Cs-137 sources were used. The well-known reference activity of the phantom was in the range of 2.5 kBq to 16 kBq, depending on the weight. Three types of mobile whole-body counting systems with different measuring geometry (bed-type, chair-type and stand-up) have been compared. Generally a good correspondence between the ten involved devices was observed. In most cases the relative bias of the measured values referring to the certified phantom activity was in the range of ± 10 %.

In November 2001 and November 2003 the Fastscan system participated in a national intercomparison between German whole-body counters organized by the Federal Office for Radiation Protection (BfS);
in both cases the relative bias of the Cs-137 measurements was below 5 %, which ensures the suitability of the German counters as ‘reference’ instruments for intercalibrations.

Further details of the measuring equipment, calibration methods and quality assurance procedures are described in another contribution to this conference by Schläger et al. [5].

All Cs-137 body burdens of children have been measured with SCRINNER-3M monitors which were previously checked in an intercomparison. MDA’s were sufficient for children with relevant contaminations. From the measured activity an internal dose was determined for each child. Dose factors were taken from Hille et. al. [1]. Additionally the mean internal dose for all examined children of a place and the mean internal dose for the ‘critical group’ (i.e. the ten children with the highest dose) were calculated for each place where measurements had been carried out. Finally the total dose for each child and for the mean values was calculated as the sum of internal dose and external dose, which can be assessed from the soil contamination in the respective place and for the purpose of the reported work is assumed to be the same for each child in a settlement.

4. Results

Previously measurements of the Cs-137 body burden of children in contaminated regions of Belarus had been performed by the Institute for Radiation Safety (BELRAD), Minsk, from 1996 to March 2002 in 152 settlements. They altogether included 21408 children out of 47119 living there. The individual dose information has been used to calculate mean internal doses and mean effective doses for both the total group of measured children in a given settlement and the critical group.

For further evaluation four subgroups have been considered:
- settlements where the mean effective dose of the critical group exceeded 1 mSv/a (subgroup 1),
- settlements where the mean effective dose of the critical group was in the range of 0.8 mSv/a to 1.0 mSv/a (subgroup 2),
- settlements where the mean effective dose of the critical group was in the range of 0.3 mSv/a to 0.7 mSv/a (subgroup 3),
- settlements where the mean effective dose of the critical group was below 0.3 mSv/a (subgroup 4).

Table 1 summarizes results obtained for all 4 subgroups.
Fig. 2. Arithmetic means of internal doses for different settlements (left) and counties (right) included in BELRAD field measurements in 2003 (age group 1-19 years). Error bars given represent the standard deviation of the mean value.
Table 1: Summary of results obtained from BELRAD data between 1996 and March 2002

<table>
<thead>
<tr>
<th>Group</th>
<th>number of settlements</th>
<th>number of measurements</th>
<th>Range of external dose [mSv/a]</th>
<th>Range of mean internal dose [mSv/a]</th>
<th>Range of mean internal dose (critical group) [mSv/a]</th>
<th>Range of mean effective dose (critical group) [mSv/a]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>34</td>
<td>5559</td>
<td>0.1 – 1.0</td>
<td>0.1 – 1.4</td>
<td>0.6 – 3.8</td>
<td>1.1 – 4.6</td>
</tr>
<tr>
<td>2</td>
<td>23</td>
<td>2776</td>
<td>0.1 – 0.6</td>
<td>0.1 – 0.4</td>
<td>0.2 – 0.9</td>
<td>0.8 – 1.0</td>
</tr>
<tr>
<td>3</td>
<td>66</td>
<td>8660</td>
<td>0.0 – 0.3</td>
<td>0.1 – 0.2</td>
<td>0.1 – 0.6</td>
<td>0.3 – 0.7</td>
</tr>
<tr>
<td>4</td>
<td>29</td>
<td>4413</td>
<td>0.0 – 0.1</td>
<td>0.0 – 0.1</td>
<td>0.1 – 0.2</td>
<td>0.0 – 0.2</td>
</tr>
<tr>
<td>Total</td>
<td>152</td>
<td>21408</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The results obtained in part I of the project were used to decide on settlements to be included in serial measurements of part II. A total of 85 out of the 152 settlements were selected. Though the main criterion was the effective dose of the critical group being higher than 0.3 mSv/a, for practical reasons not every settlement of subgroup 3 could be included. It was also clear that the possibility to include additional settlements during the course of the works should remain.

The serial measurements started in 2002 and continued into 2003. Finally about 17000 measurements could be included into the evaluation of the data. As an example of results achieved figure 2 shows the mean internal doses for measurements accomplished in 2003. For the 1-19 years old Malinovka and Skorodnoe have clearly the highest arithmetic mean value for the internal dose out of the settlements investigated in that year. The bulk of the settlements show rather moderate mean internal doses between 0.05 and 0.1 mSv/a.

![Mean of internal doses](image)

Fig. 3. Detailed results obtained for two selected settlements. The arithmetic mean of the internal dose is shown for different age groups as well as the critical group. Numbers at the bars indicate the number of persons measured.
A more detailed evaluation can be done by distinguishing different age groups. As an example for results obtained figure 3 shows mean internal doses for Malinovka and Skorodnoe. The four different age groups are 1-4 years, 5-9 years, 10-14 years and 15-19 years. Additionally the value for the critical group (1-19 years) is shown. Soil contamination, and thus the external dose derived from it, are comparable in both places.

In Malinovka for the two age groups above 10 years the internal dose is clearly higher than for younger children. This may indicate differences in the food consumed. In Skorodnoe the dose load is more equally distributed between all age groups up to 14a. However, also in this place the mean internal dose is clearly higher for young people of age 15 and more. Obviously values of body burdens are wider strewn in Malinovka than in Skorodnoe. This shows up in the mean internal doses of the critical group. Whereas in Skorodnoe this value is not much higher than the mean value of the fourth age group and below 0.5 mSv/a it reaches 1.2 mSv/a in Malinkova, i.e. the dose limit of 1 mSv/a is already exceeded alone by the internal dose

5. Conclusions and future work

From our data it is obvious, that the international dose limit of 1 mSv/a for the general population can be exceeded in some settlements of Belarus at least for some children (critical group) even still today. Though the same data indicate that there is no necessity to dramatize the situation, means of reducing doses ought to be sought for those exceeding the dose limit.

Means like restoration of agricultural land had been investigated in the past and generally contribute to a reduction of food contamination already. Also the use of clean food and the control of food contamination has generally proven its effectiveness and the latter is exercised by official authorities and private initiatives.

In this situation the clarification of the usefulness of additional means, such as the cure-like use of pectin preparations, makes perhaps sense. According to Belarusian legislation the use of such preparations is lawful and to a certain extent it is already practiced. However, previous systematic investigations suffer from small case numbers and lack of validation. During part III of the project hence special attention will be given to the effect of cure-like applications of pectin preparations on the Cs body burden of children.

On the basis of the results from the serial measurements of part II for the effective dose of the critical group 23 villages have been selected for further investigations. They are concentrated in the counties of Chechersk, Elsk, Kalinkovitchi, Korma, Lelchitsi, Narowlja, Stolin, Vetka and Zhitkhovitchi.

Between 1000 and 3000 children will take part in a double-blind study during their 3-week stay at a Belarusian sanatorium. Basic medical checks will be included into the study. At the beginning of the stay whole-body measurements will be performed. Then part of the children will receive an application of pectin preparations, whereas another part will receive placebos. At the end of the stay the whole-body counting measurements are repeated. Also selected foodstuff will be examined for radioactive contamination. In a second step a field study may be performed in several settlements involving up to 5000 children, including some measurements of the external dose in each of these settlements.

The authors are deeply convinced that nearly 20 years after the Chernobyl accident doses above the international dose limit of 1 mSv/a are no longer acceptable by ethic reasons, especially not for children. Therefore, honest efforts must be performed to reach this goal. The final results of the study may serve as basis for the decision whether and which measures can contribute to an effective reduction of the internal dose if necessary. Thus, established methods will be available for the introduction of effective countermeasures in the case of a radiological state of emergency.
**Acknowledgements**

The authors thank the German Federal Office for Radiation Protection (BfS) for funding the project under contract BfS StrSch4350.

The contribution of Dr. Vitali Vogel to part of the data evaluation is gratefully acknowledged. The assistance of J. Höbig, G. Henschke, L. Henschke, H. Mertens and T. Opitz in the field missions has been very much appreciated, as well as the dedication shown by BELRAD staff members in their field work. Thanks are also due to L. Webb for proof reading.

**References**