Urinary Iodine Concentrations in Urban and Rural Areas around Chernobyl Nuclear Power Plant

YASUYUKI TAIRA*,***, NAOMI HAYASHIDA*, SERGEY ZHAVARANAK#, ALEXANDER KOZLOVSKY##, ANATOLY LYZIKOV##, SHUNICHI YAMASHITA** AND NOBORU TAKAMURA*

*Department of Radiation Epidemiology, Nagasaki University Graduate School of Biomedical Sciences, Nagasaki, Japan
**Department of Molecular Medicine, Nagasaki University Graduate School of Biomedical Sciences, Nagasaki, Japan
***Nagasaki Prefectural Institute for Environmental Research and Public Health, Nagasaki, Japan
#Belarussian Medical Academy for Postgraduate Education, Minsk, Belarus
##Gomel State Medical University, Gomel, Belarus

Abstract. In 2007, we screened urinary iodine (UI) concentrations in urban (Gomel city) and in rural areas (Hoiniki city) of the Gomel Region, Republic of Belarus, which was heavily contaminated by the accident at the Chernobyl Nuclear Power Plant, in order to evaluate the current state of iodine supplementation in these areas. Median levels of UI were 220.5 µg/L (151.5–358.5) µg/L in Gomel city, and 228.0 µg/L (130.0–337.5) µg/L in Hoiniki city. Urinary concentrations in Gomel city were significantly improved, as compared to our previous results in 2000 (p<0.001). There were no differences of UI concentrations between Gomel city and Hoiniki city (p = 0.39), and none of the samples showed moderate (<50 µg/L) or severe (<20 µg/L) iodine deficiency in either city. These results suggest that the state of iodine supplementation has improved in rural areas, as well as in urban areas in the Republic of Belarus, probably due to appropriate fortification of iodized salt in this region.

Key words: Urinary iodine, Chernobyl Nuclear Power Plant, Iodized salt, Iodine deficiency

TWENTY-TWO years have passed since the Chernobyl accident, the worst nuclear accident in history. Medical examinations aimed at children performed within the framework of the International Programme on the Health Effects of the Chernobyl Accident (IPEHCA) and the Chernobyl Sasakawa Health and Medical Cooperative Project have shown a significant increase in the incidence of childhood thyroid cancer [1, 2]. In particular, in the Gomel region of the Republic of Belarus, a dramatic increase of thyroid cancer had been observed. In 2006, the World Health Organization (WHO) reported that the overall number of thyroid cancer cases diagnosed in Belarus, Ukraine and in the four most contaminated regions of Russia during 1986–2002 is above 4,000 among children and adolescents [3]. Over 2,000 cases were reported in Belarus alone.

One of the major components of the radionuclides released by the accident was iodine-131 (131I). Radioactive iodine fallout led to considerable exposure in the population residing around the Power Plant through inhalation and ingestion of contaminated foodstuffs [3], which may have induced the increase in thyroid cancer after the accident. In a thyroid screening study, Shibata et al. compared the incidence of thyroid cancer in children born before April 26, 1986, during 1986, and after 1986 and found that that none of children born after 1986 had thyroid cancer, which strongly suggests that internal radiation exposure by short-lived radionuclides, such as 131I contributed the increased incidence of thyroid cancer after the accident [4].
Experimental studies have shown that iodine deficiency may be an important modifier for the risk of radiation-induced thyroid cancer [5–7]. Iodine deficiency affects both the dose received by the thyroid gland at the moment of exposure, and if maintained, can affect thyroid function in the time after exposure [2, 8, 9]. Previous reports have shown that endemic goiter is relatively common in areas of Ukraine and Belarus due to iodine deficiency [10]. Ashizawa et al. screened urinary iodine (UI) concentrations around Chernobyl between 1991 and 1996, and confirmed an endemic iodine-deficient zone within this area [11]. Ishigaki et al. screened UI concentrations in the Gomel region in 2000, and showed that median UI concentration was 47.3 µg/L [12]. Tronko et al. also evaluated urinary iodine (UI) concentrations in subjects who participated in the Ukrainian-American Cohort Study, and reported median UI concentrations of 41.7 µg/L for 1998–2000 and 47.5 µg/L for 2001–2003 [13], concluding that UI levels remained at mild-moderate deficiency levels in this area.

In 2005, we screened UI concentrations in Kiev, Ukraine, and showed that median UI concentration was 109 µg/L, and only 10 of 100 subjects (10%) showed moderate iodine deficiency (<50 µg/L), with none showing severe iodine deficiency (<20 µg/L), which suggested that iodine status in Ukraine is improving, probably due to supplementation with iodized salt [14]. We also screened UI concentrations in Semipalatinsk, Republic of Kazakhstan, and found no clear evidence of iodine deficiency in this area [15, 16], which suggests that socio-medical prophylaxis against iodine deficiency has been successfully implemented in the former USSR, mainly due to iodized salt.

In this study, we screened UI concentrations in urban (Gomel city) and in rural areas (Hoiniki city) of the Gomel Region, Republic of Belarus, in order to evaluate the current state of iodine supplementation in urban and rural areas of this country.

**Materials and Methods**

**Subjects and Samples**

Prior to this study, ethical approval was obtained from the special committee of Nagasaki University (project registration number: 14032639). After obtaining informed consent, we collected morning spot urine samples in Gomel city (n = 100; total population number: 481,000 in 2005), capital of the Gomel Region, and in Hoiniki city (n = 126; total population number: 17,000 in 2005), a rural town in the same Region. The location of each city is shown in Fig. 1. All samples were kept at 4°C until assay.

**Measurement of urinary iodine**

UI concentration was measured by the “simple microplate method”, based on the Sandell-Kolthoff reaction [17], incorporating both the reaction and digestion processes in microplate format, as described elsewhere [18]. Briefly, using a specially designed sealing cassette to prevent the loss of vapor and cross-contamination among plates, ammonium persulfate digestion was performed in a 96-well microtiter plate (MicroWell; Nalge Nunc International) in an oven at 110°C for 60 min. After digestion, the mixture was transferred to a transparent microplate and the Sandell-Kolthoff reaction was performed at 25°C for 30 min. Finally, UI concentration in each well was measured by microplate reader at 405 nm. The sensitivity of this method is >10 µg/L.

**Statistical Analysis**

UI concentrations were expressed as “medians (25th–75th percentiles)”. According to the criteria of WHO, we defined mild iodine deficiency as 50–99 µg/L, moderate iodine deficiency as 20–49 µg/L, and severe iodine deficiency as less than 20 µg/L [19].
The results obtained at Gomel city were compared with previous results obtained in 2000 (n = 100) [12]. Differences in UI concentrations were evaluated by Mann-Whitney's U-test. Probability values of less than 0.05 were considered indicative of statistical significance. All statistical analyses were performed using SPSS v16.0 software (SPSS Japan, Tokyo, Japan).

Results and Discussion

UI concentration was 220.5 µg/L (151.0–358.8) in Gomel city, and was 228.0 µg/L (130.0–337.5) in Hoiniki city, respectively (Fig. 2). There were no significant differences in UI concentration between the two cities (p = 0.39). In Gomel city, UI concentrations were significantly improved when compared to our previous results in 2000 (220.5 µg/L (151.0–358.8) vs. 47.3 µg/L (35.9–76.5), p<0.001, Fig. 3). In 2000, 34% showed mild deficiency, 42% showed moderate deficiency and 10% showed severe deficiency in Gomel city (Table 1), whereas in 2007, only 7% of subjects showed mild UI deficiency (<100 µg/L) in Gomel city, and 11% showed mild UI deficiency in Hoiniki city. However, no one showed moderate and/or severe deficiency in either city.

The present results suggest that the state of iodine supplementation has markedly improved in Gomel city since 2000. Furthermore, we showed that there were no differences in UI concentration between urban and rural areas of the Gomel region, which suggests that iodine supplementation has successfully been implemented in both rural and urban areas. To our knowledge, this is the first report to show that both urban and rural areas of the Gomel region, Republic of Belarus, are no longer iodine deficient. During the current survey, we visited a local market and confirmed that all commercially distributed salts were iodized, which suggests that the improvement of iodine supplementation status in this area is due to appropriate fortification of iodized salt.

Recently, Cardis et al. analyzed the interaction between radiation dose and iodine deficiency on the risk of thyroid cancer in Belarus and Russia, and confirmed a significant interaction between dose, iodine levels in soil and risk of thyroid cancer [20]. Shakhtarin et al. also performed a similar study in the Bryansk region, Russia, and found a joint effect of radiation dose and iodine deficiency [21]. These results suggest that supplementation with iodine in deficient areas is needed in order to reduce the possible future risk of radiation-induced thyroid cancer around Chernobyl, as well as to reduce the risk of thyroid diseases, such as endemic goiter and congenital hypothyroidism.

In Belarus, early studies showed that the prevalence of endemic goiter due to iodine deficiency was mild to moderate [10]. A considerable decrease in the prevalence of endemic goiter was achieved between 1970 and 1980, but an overall rise was seen before 1990. As locally produced foodstuffs and water in Belarus had low iodine contents [10], this rise was probably due to political changes in the former USSR and Republic of Belarus, and the resulting lack of iodine supplementation in salt. Since 1999, large amounts of iodized salt have been supplied in Belarusian market [22]. However, there were still marked gap of iodized salt distribution between urban and rural areas of Belarus.
Actually in 2003, households using adequate iodized salt were 83% in Minsk (capital of Belarus), whereas those in Gomel region (including Gomel and Hoiniki cities) region were 51% [23]. In this study, we demonstrated that iodine is now appropriately supplemented in rural and urban areas of the Gomel region. This suggests that iodine supplementation in salt is effective in rural areas, as well as urban areas of Belarus. As a high incidence of thyroid cancer had been observed in rural areas of Belarus, particularly in Hoiniki city in the Gomel region [24], careful follow up of iodine supplementation status, as well as of thyroid cancer incidence, is needed.

There are several limitations in the current study. We were able to collect urine samples only in Gomel and Hoiniki cities. Further collection is needed in other rural cities of the Gomel region, and in other contaminated areas. In addition, we did not perform morphological or immunological screening of thyroid glands in this area. Previously, we screened the prevalence of positive antimicrosomal antibodies and antithyroglobulin antibodies by sex and age at the time of examination in children aged 0–10 years at the time of the Chernobyl Nuclear Power Plant accident and examined at Gomel region in 1991–1996 [25]. Recently, Agate et al. also screened for the prevalence of antithyroglobulin and antithyroperoxidase antibodies in 1999–2001, and showed that the prevalence of antithyroperoxidase antibodies in adolescents exposed to radioactive fallout remained elevated in Belarus at 13–15 years after the accident, without thyroid dysfunc-

Table 1. Summary of UI concentration of each region and the number of cases (%) with iodine deficiencies

<table>
<thead>
<tr>
<th>Region</th>
<th>Median UI concentration (µg/L)</th>
<th>50–99 µg/L (mild deficiency)</th>
<th>20–49 µg/L (moderate deficiency)</th>
<th>&lt;20 µg/L (severe deficiency)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gomel (2000)</td>
<td>47.3</td>
<td>34/100 (34%)</td>
<td>42/100 (42%)</td>
<td>10/100 (10%)</td>
</tr>
<tr>
<td>Gomel (2007)</td>
<td>220.5</td>
<td>7/100 (7%)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Hoiniki (2007)</td>
<td>228.0</td>
<td>14/126 (11%)</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

thyroid status, including UI concentrations, particularly in young adults who were children at the time of the Chernobyl Nuclear Power Plant accident is required in order to control the radiation health risks in this area.

**Acknowledgements**

This work was supported by the Foundation for Growth Science and the Ministry of Education, Culture, Sports, Science and Technology of Japan through the Nagasaki University Global COE program. We would also like to thank Ms. Miho Yoshida for her technical assistance.

**References**

7. Ohshima M, Ward JM (1986) Dietary iodine deficien-