ABSTRACT

Objectives. The present study is a pilot project for the Finnish AMAP (Arctic Monitoring and Assessment Programme / Human Health) investigations. We examined the exposure of northern Finns to chromium (Cr), because analyses of this metal are not included in the AMAP, and local industry and industry throughout the Kola Peninsula may increase chromium fallout in Finnish Lapland. Chromium exposure and its temporal trend were estimated by analyzing hair of northern Finns collected in 1982 and 1991.

Methods. After washing the hair samples, chromium analyses were carried out in 1995 by a method developed by Salmela et al. (1981) and Kumpulainen et al. (1982). The Perkin-Elmer 5000 atomic absorption spectrometer used was equipped with a graphite furnace (HGA-400).

Results. Age showed no statistically significant correlation with Cr concentration in hair, but the hair concentration of Cr in men was higher than that in women, both among southern and northern Finns and Sami.

Conclusions. Chromium levels in the hair of Finns and Sami were too low to result in any health hazard, however, exposure to chromium may have slightly increased during the 1990s.

Keywords: chromium, hair, northern Finns, health
INTRODUCTION

Industrial pollutants in the Kola Peninsula have increased the concentrations of several heavy metals in the environment, not only in the area of the Peninsula, but also in northern Finland. Many industrial plants are located in the Kola Peninsula, e.g. the Severonikel smelter complex in Monchegorsk, the Pechenganikel complex near the Norwegian border, and the mining towns Apatity and Kirovsk. Generally, atmospheric heavy metal levels over northern Finland have been similar to those in southern Norway, except for chromium (Cr), higher concentrations of which have been found in a few places in northern Finland (1). The main source of Cr pollution in Northern Europe is local industry, especially iron and steel mills, e.g. the Tornio steel mill in Finland and a ferrochrome smelter at Mo i Rana, Norway. Cr concentration of river water in Tornio has, according to environmental surveys of Environmental Center of Lapland ranged, from 0.25 to 1.42 µg/l. In Canada, an average of 2 µg/l of Cr is found in waterways (2). Cr concentrations in moss indicate background values about 60 times higher in the Kola Peninsula than in Lapland (3). In contrast, atmospheric Cr concentrations over northern Finland have been higher than those in southern Finland, while concentrations in moss in the Helsinki area have, in general been higher than in Lapland. Studies of heavy metals in archived moss indicate a general increase in concentrations in some regions of Northern Europe up to around 1970. In Finland, Cr concentrations have decreased slightly since 1985 (3). It has been estimated that Finnish Cr emissions have decreased from 114 t in 1979, to 28 t in 1995 (4).

The present study is a pilot project for Finnish AMAP (Arctic Monitoring and Assessment Programme) investigations. The AMAP project was established in 1991 to implement components of the Arctic Environmental Protection Strategy, as adopted by ministers of the 8 arctic countries. Phase I of the AMAP core program has focused mainly on persistent organic pollutants (POPs) and metals (Pb, Hg, Cd, Se, Zn and Cu). Since Cr fallout from local industry and throughout the Kola Peninsula may be a possible risk to Finns living in Lapland, we determined Cr concentrations in the hair of northern Finns in 1982 and 1991 to explore the levels and temporal trend of exposure to this element.
SUBJECTS AND METHODS

The subjects comprised a group of 11 persons from Ivalo (including both Sami and Finns; 5 males, 6 females) who donated both serum and hair samples in 1982 and 1991. In addition, hair and serum samples were obtained in 1991 from 7 adults from Nellim (5 males, 2 females) and 8 adults (2 males and 6 females) and 2 children from Sevettijärvi - Näätämö. For comparison, hair samples from 23 deceased persons (16 males, 7 females) who had resided in the Helsinki area and died in 1982-1984 of accident or sudden illness were studied. We have already reported the Hg, Zn and Cu concentrations in hair, and of Se, Cu and Zn in the sera, of these persons (5).

Hair samples were collected by taking a small tuft of hair from behind the ear and tying it up with cotton. For the analyses, about 2 cm (0.5 g) was taken. Washing of hair samples was carried out first with hexane and then 4 times with 1% sodium lauryl sulphate (6).

Persons from Ivalo completed a questionnaire in 1982 and 1991, in which age, height, weight, occupation, dietary habits, smoking habits, drinking of alcoholic beverages and fishing habits were explored. In addition, the names of shampoos they had recently used were asked.

Cr analyses were carried out in 1995 by a method developed by Salmela et al. (6) and Kumpulainen et al. (7). The Perkin-Elmer 5000 atomic absorption spectrometer used was equipped with a graphite furnace (HGA-400). Our equipment was exactly the same type as used in the development of the method (7). The limit of detection for the method used is about 0.3 ng Cr / ml defined as blank + 3 SD. When Cr contents are about 0.20 µg/g, the day-to-day variation of the precision (RSD) is less than 10 %. The validity of the entire measurement procedure was checked by employing National Bureau of Standards (NBS) Standard Reference Material from Bovine Liver (SMR 1577, certified value 0.08 ± 0.012 µg Cr/g) as an internal standard. In each sample set reference material and several blanks were analyzed simultaneously. The accuracy of the analytical method was good: four NBS samples yielded a value of 0.086 ± 0.013 µg Cr /g (mean ± SD).
STATISTICAL METHODS

Statistical analyses were performed with the BMDP program package (8). Non-parametric methods: Spearman’s rank order correlation, the Mann-Whitney test and Wilcoxon’s signed rank test were used in the statistical analyses.

RESULTS

Age showed no statistically significant correlation with Cr concentration in hair. In contrast, the hair concentration of Cr in men was higher than that in women, among both southern and northern Finns and Sami (Table I). In 1991, the difference in northern Finns between males and females was, on average, 0.17 µg/g (p = 0.002), while the 95% confidence intervals of the difference ranged from 0.07 to 0.27. No statistically significant differences in Cr concentrations were found in persons residing in different parts of northern Finland. The number of cases was, however, too small to draw any firm conclusion. During the period of 1982-1991, Cr levels in the hair of persons residing in Ivalo were, in general, unvarying, or were slightly increased (p = 0.02) in all but one man (Fig. 1). His Cr concentration was exceptionally high in 1982 and was still among the highest found in men from Ivalo in 1991.

Table I. Concentration of chromium in hair of adult northern Finns and Sami and southern Finns.

| Area    | Females mean (µg/g) | Males mean (µg/g) | Females mean (years) | Males mean (years) |
|---------|---------------------|-------------------|----------------------|--------------------|
|         | range (N)           | range (N)         | (range)              | (range)            |
| 1991    |                     |                   |                      |                    |
| Ivalo   | 0.19                | 0.32              | 36                   | 39                 |
|         | 0.11-0.26 (6)       | 0.24-0.39 (5)     | (35-51)              | (34-57)            |
| Nellim  | 0.10                | 0.41              | 54                   | 46                 |
|         | (1)                 | 0.20-0.68 (5)     | (34-58)              |                    |
| Sevettijärvi | 0.15              | 0.29              | 49                   | 59                 |
|         | 0.09-0.45 (6)       | 0.07-0.51 (2)     | (30-67)              | (53-67)            |
| All     | 0.18                | 0.36              | 46                   | 5                  |
|         | 0.09-0.45 (13)      | 0.07-0.68 (12)    | (30-67)              | (34-67)            |
| 1982    |                     |                   |                      |                    |
| Ivalo   | 0.11                | 0.33              | 28                   | 31                 |
| 1980s   | 0.09-0.15 (7)       | 0.16-0.54 (5)     | (26-42)              | (25-48)            |
| Helsinki area | 0.13           | 0.28              | 53                   | 44                 |
|         | 0.08-0.24 (7)       | 0.09-1.00 (16)    | (29-83)              | (17-68)            |

Cr concentration in hair of 7- and 14-year-old boys in Sevettijärvi were, 0.22 and 0.25 µg/g, respectively.
The geometric mean concentration of Cr in the hair of 16 southern Finnish males and 7 females varied from 0.21 to 0.13 µg/g during 1982-84. Corresponding values in early 1980 for Ivalo residents were 0.30 µg/g for men and 0.11 µg/g for women. Cr concentrations showed no statistically significant correlations with Hg, Zn, or Cu concentrations in hair, nor with dietary, drinking, or smoking habits. This may be due to the longer accumulation time of Cr in hair compared with that for other heavy metals, e.g. Hg.

Figure 1. Trend of Cr concentrations of 11 persons (5 males, 6 females) residing in Ivalo from the year 1982 to 1991.
DISCUSSION

Tissue samples may become contaminated with Cr during sampling, sample handling and analysis steps. This is probably the most difficult aspect of Cr analysis at the ultratrace concentration level. Needles and knives employed for venipuncture, or other tissue biopsies, are usually made of stainless steel, which contains 8-20 % Cr. Use of normal venipuncture needles may introduce a Cr contamination into the blood, or liver biopsy samples that is 100 times higher than the amount that is naturally present (9,10). Hence, we used blood samples drawn from northern Finns with stainless steel needles only for analyses of metals other than Cr, which we reported earlier (5). In the present study, the hair samples used were cut with a Cr-free Ti knife to avoid Cr contamination.

Cr emissions into the environment are predominantly derived from fuel combustion, waste incineration and industrial processes. The less toxic trivalent form of Cr, Cr(III), is predominant in most environmental compartments. The principal source of exposure to Cr is food, but the main source of Cr in the diet is not known. In the United Kingdom, milk and dairy products contribute most to the daily dietary Cr intake, followed by sugars, preservatives, potatoes, oils and fats (11,12). Part of the Cr is dissolved from steel processing and cooking equipment by acidic foods, but this contribution to the daily intake is not expected to exceed 50 µg/day (13). Active and passive smoking can also increase the daily Cr intake by 2-12 µg/day. Inhalation is a minor route of exposure for the general population (12). Cr exposure from consumer products may also occur through dermal contact, although Cr(III) is very poorly absorbed through the skin (14). Products used in daily life often contain Cr compounds, such as those found in Cr ores, baths, coloring agents, lubricating oils, anticorrosive agents, wood preservation salts, cleaning materials, textiles, leather tanned with Cr compounds, tattooing, and metal pins and trinkets (12,14).

Estimates of Cr intakes for the general population have generally ranged from 50 to 200 µg/day (12,14). The mean calculated per capita Cr intake for Finland calculated in the late 1970s was low, in the range of 29 µg/day (15). Dairy products, vegetable foods and meat were all estimated to contribute about 20% of the daily intakes of Cr (15). Accordingly, the average maternal diet of lactating Finnish mothers at that time was estimated to provide approximately 30 µg Cr /day
In the late 1990s, using the Nutrica calculus of the Finnish Social Insurance Institute, we calculated that the mean intake of Cr among lactating mothers in Finnish Lapland was similar, 25 µg/day (17).

The percentage of Cr absorbed from food in the human gastrointestinal tract is small, with an average of 0.5% (18). Cr absorbed into the organism is cleared rapidly from the bloodstream and is excreted, or taken up by the tissues (19). It is not known whether any particular organ is responsible for storing and releasing metabolically responsive Cr. Hair appears to reflect the nutritional Cr status. Hair Cr concentrations in children were found to be significantly higher during the first 6 months of life than at any other age (14).

The hair Cr content of Finns and Sami indicates that Cr exposure of these people was low in the 1980s and 1990s, as suggested by Finnish dietary calculations reported in the literature. Hair Cr levels in inhabitants of northern and southern Finland are similar and in general lower than those reported in non-industrial areas of other parts of the world, e.g., in northern Alberta, Canada (20, 21). The higher concentrations of Cr in males compared with females may not be explained by dietary composition. For example, chromium is not known to be concentrated in reindeer tissues (15). We suggest that the difference may be partly explained by the greater volume of food consumed by males. Males may also be contaminated when operating machinery using Cr-containing lubricating oils, or fuels.

Cr in the hexavalent form, Cr(VI), has been recognized as a carcinogen. The human body has effective detoxification mechanisms that can reduce ingested, or inhaled Cr(VI) to Cr(III). Most of the reported adverse health effects are associated with occupational exposures. The US. Environmental Protection Agency (EPA) has established a reference dose of 1000 µg/kg body weight for Cr(III). The National Research Council (NRC) has proposed that the daily recommended intake range should be 50-200 µg per person per day (22). Adequate dietary Cr is required to maintain normal glucose tolerance, as well as normal cholesterol metabolism. Rowbotham et al. (12) recently completed a very thorough risk estimate to human health of the exposure to environmental levels of Cr. Based on these estimates, exposure to Cr among northern Finns and Sami does not result in health hazards. We also suggest that exposure to Cr may have slightly increased among women during the 1990s (Fig. 1), but, due to the small number of cases, it is difficult to explore the reasons for this.
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