

THE USE OF NUCLEAR AND RELATED TECHNIQUES FOR THE STUDIES OF POSSIBLE HEALTH IMPACT OF AIRBORNE PARTICULATE MATTER IN A METAL INDUSTRY

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1. INTRODUCTION

Various processes in an industry may produce gases and fine airborne particulate matters. Elements and hazardous chemicals in the fine particulate matters may enter human body through inhalation and direct contact with the skin. Excessive inhalation and contact with the fine airborne particulate matter may lead to intoxication due to excessive intake of the hazardous chemicals and toxic elements. The elements will be accumulated in human organ, such as liver, kidneys and brain, manifest in clinical syndromes such as hypertension, renal failure and neurological symptoms and signs. The absorbed elements are excreted through urinary tract as urine. They also can be excreted through hair and nails. Elevated blood and urinary aluminum levels have been observed after occupational exposure to various aluminum compounds. This phenomenon indicates the absorption through inhalation, as there are no data indicating significant dermal absorption for aluminum¹. Absorption of chromium compounds in the workplace occurs mainly through inhalation. The absorption is dependent on the valence and solubility of the particular chromium species. Some elements such as trivalent chromium ions are readily cleared from the blood, but hexavalent chromium ions are retained much longer in the blood. The aluminum compounds vary greatly in their toxic and carcinogenic effects². Although the trivalent chromium is readily excreted, continuous intake may cause the blood chromium level higher than normal. These elements may either have deleterious effect on, or considered essential for human health. In this study, the levels and health effects of airborne particulate matter in the workplace is assessed by elemental quantification of blood, hair and nail of workers in a metal industry and in airborne particulate samples that are collected at the workplace. The present report represents progress of activities following the first Research Co-ordination Meeting 1997 in Vienna.

2. METHODS

Airborne particulate samples were collected from halls or buildings where the workers carry out their work. The sample collection was carried out during working hours (from 9 a.m. to 4 p.m.). The airborne particulate matter was deposited on pre-weight Nuclepore filter using a Gent sampler. The Gent sampler separated the particulate matter into two fractions, i.e. coarse (aerodynamic diameter $<10 - 2.5 \mu\text{m}$) and fine ($<2.5 \mu\text{m}$) fractions. Prior weighing until constant weight, the filter was equilibrated in a preconditioned chamber at 25°C, 50% relative humidity. The amount of the deposited airborne particulate matter on the filter was determined by weight difference of the filter before and after sample collection. Elemental levels in the samples were determined by instrumental neutron activation analysis (INAA). Short lived induced radioactivity measurement was performed by irradiation the sample in a

¹ Biological Monitoring of Chemical Exposure in the Workplace, Vol. 2, World Health Organization, Geneva 1996, 92.

² Biological Monitoring of Chemical Exposure in the Workplace, Vol. 1, World Health Organization, Geneva 1996, 93-94.

neutron flux of $10^4 \text{ n cm}^{-2} \text{ sec}^{-1}$ for 20-30 seconds, and promptly counting the induced radioactivity in the irradiated sample on a gamma ray spectrometer. Quantification of elements that produced long lived induced radioactivity were accomplished by irradiation the sample in a neutron flux of $10^4 \text{ n cm}^{-2} \text{ sec}^{-1}$ for 30 minutes, and following 2-3 weeks cooling the sample was counted using a high resolution gamma ray spectrometer.

Elemental levels in serum sample was determined by neutron activation analysis and graphite furnace atomic absorption spectrometry (GF-AAS). Irradiation and counting conditions for NAA of serum sample was similar to that of airborne particulate sample. To accomplish GF-AAS, 2 cm^3 of concentrated HNO_3 (suprapure from E. Merck) was added to 0.1 g of freeze dried serum in a 30 cm^3 teflon beaker. Covered by a teflon plate. The reaction mixture in the teflon beaker was heated and boiled until no release of brown fumes. The amount of the sample solution was determined by weighing. A blank solution was prepared in the same way as the sample, but with no serum. The blank was used to correct the concentration of the element to be determined. A second generation of Versieck serum reference material is used to validate the analytical procedure. To suppress surface contamination from the container, the teflon beaker was used to boil concentrated nitric acid several times before being used to dissolve the serum sample. Atomisation of aluminum was performed following the addition of sufficient amount of phosphoric acid.

3. RESULTS AND DISCUSSION

Elemental determination in the airborne particulate sample was validated using reference material pond sediment, for Al was found $104 \pm 7 \text{ mg/g}$ (certified value $106 \pm 5 \text{ mg/g}$) and for Zn was found $331 \mu\text{g/g}$ (certified value $343 \pm 17 \mu\text{g/g}$) and coal for Zn (found 37 ± 6 and certified value $30.2 \pm 1.9 \mu\text{g/g}$).

Neutron activation analysis of the deposited airborne particulate matter collected in late 1997 (October-November) was found that the sample was enriched by zinc and chromium. The range of enrichment factor (reference element was scandium) for zinc in fine fraction was 5 (smelter department) – 30 (painting department), but mostly ca. 10. No significant enrichment factor for chromium in fine fraction. In coarse fraction, the lowest enrichment factors for chromium and zinc were respectively 3 and 16, all were represented by samples from smelter department, and the highest were 195 for chromium and 95 for zinc and all were represented by samples from heat treatment department. The enrichment factor for chromium and zinc in airborne particulate samples collected in late 1998 were lower, i.e. respectively up to 10 for chromium and zinc in fine fraction. In coarse fraction no enrichment were observed for these elements, except in sandblasting department (ca. 100). We consider that aluminum was enriched in all fractions, although the enrichment factor were only 5-7 and 7-8, respectively for fine and coarse fractions. The consideration was based on the fact that aluminum is abundant in nature (comprising approximately 8% of elements in the earth crust³).

Based on these observations the blood elemental levels will be focused on three elements, namely chromium, zinc and aluminum. Under our irradiation and cooling conditions, the detection limit for chromium was about 20 ng. By longer irradiation the detection limit will significantly be improved. At present longer irradiation in the multipurpose reactor for neutron activation analysis was difficult to achieve because lack of suitable irradiation container. We have such container only for irradiation in Bandung TRIGA Mark II reactor. Unfortunately the upgrading of Bandung TRIGA Mark II reactor has not been

³ J. Versieck and R. Cornelis, Trace Elements in Human Plasma or Serum, CRC Press Inc., 1989, 67-68.

completed yet. That is why we seek another analytical technique, i.e. GF-AAS [3]. The spectrometer used in this experiment was a double beam GBC 933 AA, equipped with a GF 3000 graphite furnace.

Before the determination of serum aluminum and chromium levels were performed, it was studied the critical parameters of the determination, i.e. detection limit, validity of the determination and whether the levels of the contamination was negligible. Using a pure compound it was observed that the detection limit for Cr and Al were respectively ca 1 ng/g of solution (by atomisation 100 μ l of nitric acid solution). The certified values for Al and Cr in the Versieck second generation of serum reference material was respectively 20.2 and 0.76 ng/g dry weight. If the chromium and aluminum determination was used 0.g of dried samples, the chromium level will below the detection limit and aluminum level was close to the detection limit. Consequently under the present experimental conditions, only chromium and aluminum at much higher levels than normal levels could be detected. It was also observed that levels of contamination was relatively high, i.e. 10-50 ng/cm³ (total solution was 1-2 cm³).

4. PLANS FOR FUTURE WORK

- a) Development of sample destruction techniques with acceptable contamination levels to improve the detection limit and analytical sensitivity of the GF-AAS analysis.
- b) Determination of elemental levels in freeze dried sera and tissue samples (nail & hair).
- c) Statistical evaluations to obtain possible correlations among the observed data.
- d) Further study on the possible health impacts of airborne particulate matter in the workplace of an aluminum industry.