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Original Research

Aluminium as Trace Element in Pharyngeal Tonsils

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Abstract

The aim of this study was to determine aluminium in pharyngeal tonsils taken from children living in different parts of the Silesia and Małopolska regions in Poland. Pharyngeal tonsils were taken during adenotomies performed according to the currently binding procedures. The aluminium concentration was determined by the ICP-AES method with 0.01 $\mu g \cdot g^{-1}$ accuracy using the Perkin Elmer Optima 5300DV™ horizontal plasma apparatus. The average amount that equals the geometric mean of aluminium concentration in tonsils of children from rural village areas living beside the reach of intensive influence of industrial emission was 3.39 $\mu g \cdot g^{-1}$ for comparison with an industrial region (Silesia) it was higher 16.90 $\mu g \cdot g^{-1}$. Pharyngeal tonsils of children living in Małopolska also contained about 7 times higher concentrations of aluminium – 22.91 $\mu g \cdot g^{-1}$ when compared to rural children. Aluminium concentrations in pharyngeal tonsils when gender was concerned revealed considerable differences: girls 12.94 $\mu g \cdot g^{-1}$ and boys 18.22 $\mu g \cdot g^{-1}$ ($p \leq 0.05$).

The cross-correlation analysis between contents of Al and other metals including Ba, Ca, Cr, Cu, Fe, Mg, Mn, Zn, K, Na, and Cd, in the investigated group of children was observed.

Keywords: aluminium, pharyngeal tonsils, children, human, metals

Introduction

Aluminium belongs to the most common elements in nature [1-5]. It can be found in rocks, soil, surface waters, animal and plant tissues, in drugs and cosmetics [2, 3, 5]. Untill now this element hasn't concerned toxicologists because it has been believed that aluminium is harmless to humans as it is easily removed from the organism through urine [1, 6].

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Aluminium has begun to be of more interest recently, especially due to its metabolism and toxicity. Aluminium can be toxic to humans at both environmental and therapeutic levels. Human exposure to aluminium is primarily dietary, even though occupational (industrial) exposure and medically administered aluminium (including medications antacids) [3]. It has been suggested that aluminium can be the etiological factor in the process of many diseases appearance, for example: Alzheimer's disease, disseminated sclerosis, Parkinsons, epilepsy and Down's syndrome [7-13]. Ferriera et al. showed that Al is associated with several neurophysiologic processes that are responsible for the characteristic degeneration of Alzheimer's disease [13]. Aluminium is associated with the inflammatory, responses, mediated by interleukins and other inflammatory cytokines [14].

Aluminium accumulation in bones leads to changes in P, Ca and F metabolism and ends in osteodystrophy and osteomalation (as a result of improper mineralization of hydroxyapatite) due to the way aluminium affects osteoblasts [15, 16]. Typical signs of osteomalation are higher susceptibility to bone fractures, bone pain (especially of long bones) and myotonia [17, 18].

Aluminium inhibits the synthesis of D_3 vitamin and parathormone, which leads to the reduction of calcium content in bones [19, 20]. It has been proved that parathormone increases the absorption of aluminium. Moreover, aluminium has a toxic influence on the haematopoietic system, because it bonds with transferrin and ferritin and inhibits the release of Fe ions.

People living in the territory of high aluminium compound exposure in the air tend to suffer from changes in the respiratory system, the symptoms of which are chronic unspecific lung failure, parenchymal fibrosis of the lungs, and pneumothorax [15].

The literature overview given above confirms that aluminium is a dangerous element for human beings. The common phenomenon of acid rain additionally releases the preserves of aluminium from soil to plants and, due to the alimentary chain, to animals and people. Subsequently it can end as an opening of Pandora's box: released amounts of aluminium compounds will successively intoxicate many different tissues and will slowly lead not only to the accumulation of this element, but also to severe health loss [16, 20, 21]. On the other hand, Anke et al. qualified the hypothesis of the essentiality of aluminium for animals because aluminium deficiency leads to significantly increased mortality, impaired success of first insemination, and increased rates of abortion, services per gravidity, child mortality, and mortality in the first year of life [22].

So, pharyngeal tonsils are, among all the tissues mentioned here, a good bioindicator of aluminium in the environment and a good biomarker of exposure. What is more, anatomical features and the location in the ventilation airway make pharyngeal tonsils (due to the higher accumulation of aluminium) the biological material for studies on the scope of the harmful influence that dust-containing aluminium has on humans.

Materials and Methods

Overgrowth pharyngeal tonsils taken from children living in different parts of the Silesia (industrial region) and Małopolska regions in southern Poland constituted the material of this study. They were obtained with the consideration of the following criteria:

- incorporation criteria:
  - permanent address in the area under research,
  - minimum II grade overgrowth of pharyngeal tonsil,
- exclusion criteria:
  - patients with readenothomy before,
  - prior intoxication of examined elements or other elements that can influence their metabolism or accumulation in tissues,
  - patients that have or had any kind of neoplasm,
  - patients that have primary haemochromatosis, siderosis or secondary haemochromatosis, *hepatolenticular degeneration* (Wilson's disease) or other uncommon diseases that lead to higher accumulation of examined elements in tissues,
  - patients with primary and secondary dysfunctions of absorption.

The research on the aluminium content in pharyngeal tonsils was carried out in the basis of Bioethical Commission permission (19.04.2005, L.dz. NN-6501-255/I/04/05).

Pharyngeal tonsils (n=96) were taken during adenotomy performed according to the currently binding procedures that represented different conditions of pollution in these towns. 40 pharyngeal tonsils from girls and 56 from boys were analyzed. According to the place of living, three regions were distinguished: Silesia – 55 children, Małopolska – 25 children, and rural village areas (Jura Krakowsko-Częstochowska) – 16 children. The ages of children were 2 to 15 years old (average 6.2 years).

Samples of pharyngeal tonsils were frozen at -20ºC. Specimens of pharyngeal tonsils were dried at 105ºC±2ºC in KPC-65G drier. Next, mineralization was provided as the following procedure: 1.00 g dry weight was diluted and 2 cm^3 of supra pure spectrally 65% HNO_3 (V) (Merck) and samples were warmed. The solution was transferred into a 10 cm^3 volumetric flask and filled up to the mark with redistilled water.

The aluminium concentration was estimated by the ICP-AES method using the Perkin Elmer Optima 5300DV™ horizontal plasma apparatus at Silesian University. Detectability of aluminium was 0.01 μg·g. The accuracy of determination was controlled by material reference "WZORMAT" Warsaw. The different aluminium determinations equalled about 3-5%. Aluminium content in samples was average arithmetic with six twice of repetition measurements.

The results were analyzed statistically with the program Statistica 6.1.

Results

Because total amount of aluminium in the human body equals about 30-50 mg, the proposal to estimate aluminium contents in pharyngeal tonsils was presented in Table 1.

The range of quantity changes of this element in the case of children from industrial areas of Silesia was 19.38-54.19 $\mu g \cdot g^{-1}$ and from Małopolska: 14.27-53.50 $\mu g \cdot g^{-1}$, in comparison to the rural areas (southern Poland): 2.65-3.61 $\mu g \cdot g^{-1}$. These data manifest the above given role of dust suspended in the local air emission and for localized power

Table 1. Aluminium contents in pharyngeal tonsils [$\mu g \cdot g^{-1}$].

Arithmetical mean±standard deviation	Most probably statistical range of changes	Geometric mean	Values relating to	
			10 percentile	95 percentile
Village Rural Area (Jura Krakowsko-Częstochowska)				
3.48 ± 1.13	2.65 - 3.61	3.39	2.68	4.28
Industrial region (Silesia)				
36.78 ± 22.64	19.38 - 54.19	20.29	17.00	70.11
Małopolska Region				
29.61 ± 25.72	14.27 - 53.50	22.91	10.45	58.84
Role gender in accumulation of Al - girls				
24.37 ± 27.73	2.06 - 58.80	12.94	2.68	70.11
Role gender in accumulation of Al - boys				
33.89 ± 22.01	0.16 - 50.81	18.22	17.00	61.88

plants as far as the grade of aluminium concentration of the pharyngeal tonsils is concerned [1, 2, 4, 6, 15]. Aluminium content in dust from power plants varied from 3,800 to 1,490 $\mu g \cdot g^{-1}$ [18].

For example, concentrations of dust suspended in the air in Małopolska was 47 $\mu g \cdot m^{-3}$, in rural village 33 $\mu g \cdot m^{-3}$, in industrial region (Silesia) it varied from 52 $\mu g \cdot m^{-3}$ in town (Dąbrowa Górnicza) to 113 $\mu g \cdot m^{-3}$ in town (Zabrze) [23].

In the case of surface waters, aluminium content varied from 0.15 to 0.60 $mg \cdot l^{-1}$ and its geometric mean amounts to 0.2 $mg \cdot l^{-1}$. These are the amounts that are directly bioaccessible to the population dwelling in an industrial region, rural village and Małopolska [24, 25].

The average amount that equals the geometric mean of aluminium concentration in tonsils of children from village rural areas living beside the reach of intensive influence of industrial emission was 3.39 $\mu g \cdot g^{-1}$, and in the industrial region of Silesia it was 16.90 $\mu g \cdot g^{-1}$. Pharyngeal tonsils of children living in Małopolska also contained about 7 times higher concentrations of aluminium – 22.91 $\mu g \cdot g^{-1}$, when compared to children from rural areas. The differences in aluminium contents in relation to the three investigated regions were not statistically significant.

Aluminium concentration in pharyngeal tonsils when gender was concerned revealed considerable differences – girls had 12.94 $\mu g \cdot g^{-1}$ and boys 18.22 $\mu g \cdot g^{-1}$. The difference in this metal average content gender was found to be significant ($p \leq 0.05$).

The frequency of aluminium occurrence is characterized by normal distribution nature: right-direction for girls and left-direction in boys.

The observations presented above are confirmed by the data concerning arithmetic means of the aluminium content in pharyngeal tonsils.

The changes of the aluminium content in children living in Małopolska Region were directly proportional to the ones of Ca (0.99), Fe (0.97), Mn (0.98), Na (0.99) and Cd (0.99), and inversely proportional to those of Ba (-0.67), Mg (-0.99), Zn (-0.62), K (-0.90) - Fig. 1.

Moreover, mutual interactions characterized by directly proportional changes in girls and boys were observed with reference to Ca, Fe, and Na, and they were stronger in the case of girls (Fig. 2). Inversely proportional the changes of Al to Cr (-0.98) confirm this dependence investigation Nogaj et al. were found for boys and directly proportional changes of Al to Ba (0.98) in the case of girls [26].

Directly proportional relationship Al with Ba (0.72) Zn (0.96) in femur capitulum was shown by Brodziak et al. [19]. Likely results obtained by Nogaj et al. in early investigation of aluminium contents in pharyngeal tonsil for girls and boys exposure to environmental tobacco smoking [26].

In the total population of children from an industrial region (Silesia), similar strong and directly proportional interactions of aluminium with calcium were observed (0.63) and inversely proportional with potassium (-0.52).

Discussion

Varied emission of dust from power plants that mostly contribute to total industrial emissions cause the concentrations of many elements that are present in the ground layer of the air to be much higher than would result from the geochemical characteristics of the ground [18].

Aluminium content in dust suspended in the air in the closest power plants is estimated as 82,500 $\mu g \cdot m^{-3}$. This value changes and amounts to 3.5×10^3 $\mu g \cdot g^{-1}$ at a distance of 6 km. Similarly, total aluminium fall in the nearby power plants is 6.0×10^4 $mg \cdot m^{-2}$ and at 6 km (due to compass card) it amounts to as much as 9.4×10^3 $mg \cdot m^{-2} \cdot year^{-1}$ [25].

The amount of aluminium in pharyngeal tonsils of girls varied from 2.68 to 70.11 $\mu g \cdot g^{-1}$, and in the case of boys it varied from 17.0 to 61.88 $\mu g \cdot g^{-1}$. However, the most statistically probable range of changes of aluminium was equal to 2.06-58.80 $\mu g \cdot g^{-1}$ for girls and 16.96-50.81 $\mu g \cdot g^{-1}$ for boys.

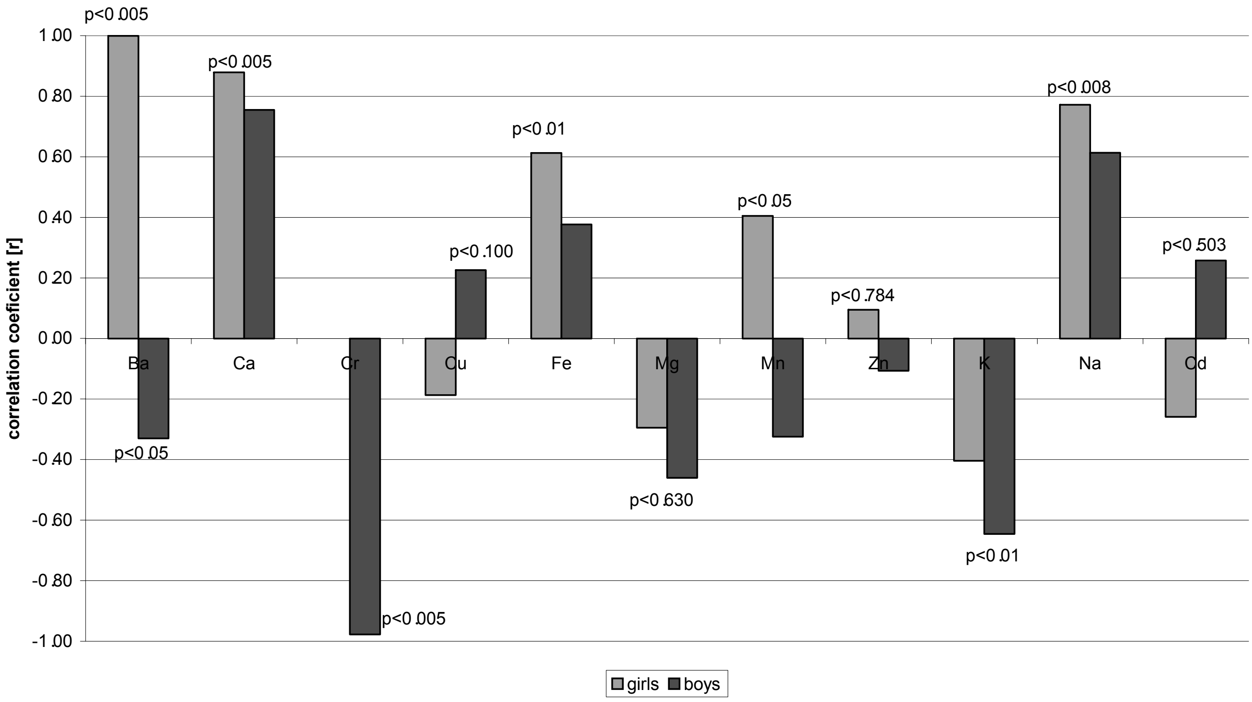

Fig. 1. Correlation between Al and other metals in pharyngeal tonsils from girls and boys living in southern Poland.

According to evidence of the greater mobility and higher ventilation of the noso-pharyngeal system, in cases during play by boys it can cause higher contamination of pharyngeal tonsils.

The role of gender confirms results correlation analysis. These perceptions are first for estimation of exposure children by aluminium.

Apart from the role of the specific way of intoxication of pharyngeal tonsils through the air inhaled by nose, the presence of aluminium can be stimulated by potential interactions with other elements in different ways as a result of interaction in bioavabilities [24].

The correlation between aluminium and the other metal contents in pharyngeal tonsils from children living in rural regions are not established in this paper. Deficiency of signification of coefficient correlation is translated to places out of industrial emission.

The problem of aluminium intoxication is worth further investigation as described by high coefficient of aluminium emission to the air that equals 1.5 near Bytom (Miechów power plant) and Będzin (Będzin power plant). This coefficient is similar to the emission coefficient of Ca, Fe, Cu, and Se, and it is bigger than the emission coefficient for Mg, Sr, and Rb – 1.0-1.2 [28]. Only around 22% of alu-

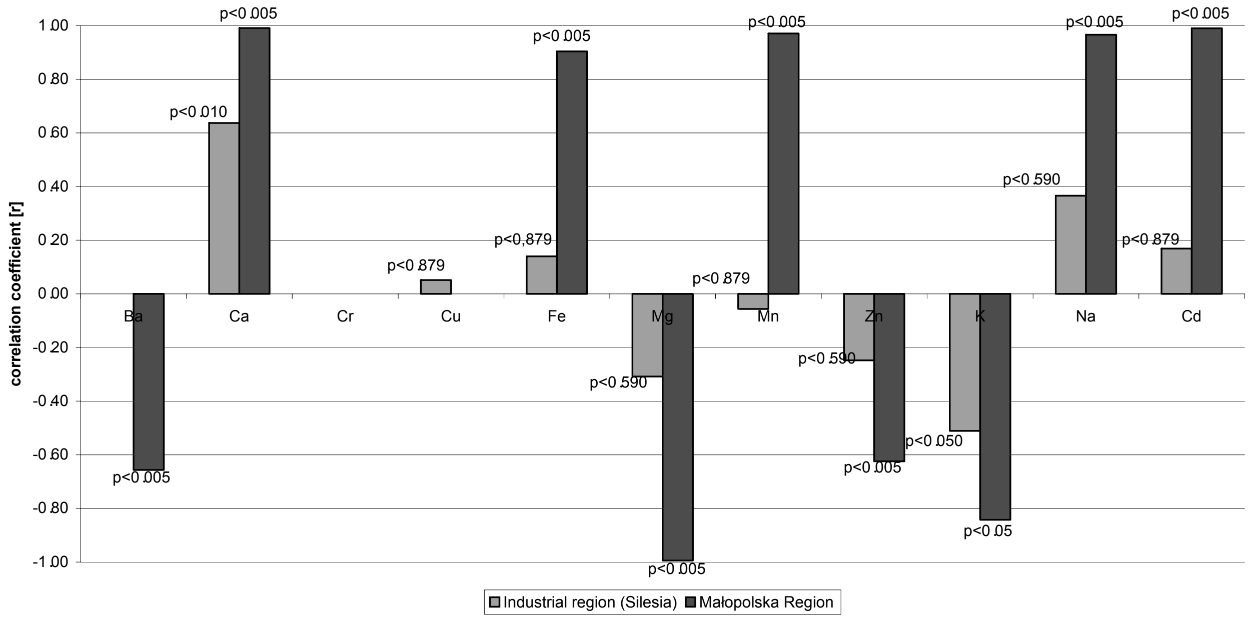

Fig. 2. Correlation between Al and other metals in pharyngeal tonsils from children living in several regions of southern Poland.

minium is maximally washed out from the air and on the average about 10% of total amount of aluminium is present in the dust of a diameter smaller than 10 μm [25, 28]. Aluminium is one of the elements that is not successfully washed out from the ground layer of the air, so risk of exposure to aluminium compounds can be found in the air long after emission. The period of falling from the air for 10 μm dust that has aluminium inside is estimated as 3 months after the emission. Different anemologic conditions (speed and direction of wind) can often cause the higher accumulation of aluminium near highly congested areas [25, 28].

The total amount of aluminium in the human body is about 30-50 mg, the half of which is in bones and one fourth in lungs [28, 29]. The content of this element in the human organism is small, because 70-97% of aluminium is excreted through the digestive system and 3-30% by kidneys [29]. An excessive dosage of aluminium leads to accumulation of this element in the brain, especially in its grey matter, and also leads to accumulation of this element in liver, kidneys, spleen, and the thyroid gland [29]. The high concentration of aluminium in the body leads to the serious disturbances in functioning of the nervous, skeletal and haematopoietic systems [15, 27].

Aluminium compounds in a living organism interfere with many indispensable metals and are able to change their bioaccessibility. Aluminium rivals with Zn, Fe, Ca and Cr [4, 24]. High aluminium intake with food leads to higher concentrations of Mg in liver and spleen of older people and decreased Zn and Cu content in kidneys and bones. In the case of lysosomes of human brain, kidneys and liver aluminium competes with phosphorus, in the case of bones with Ca and in case of nucleus with Mg [4, 19].

It has been proved that the lower the concentration of Ca and Mg in drinking water, the higher the absorption of aluminium from the digestive system and the accumulation of aluminium in the human nervous system [17].

In these conditions the accumulation of aluminium in pharyngeal tonsils is relatively high – in Silesia -70.1 $\mu g \cdot g^{-1}$ and in Małopolska 58 $\mu g \cdot g^{-1}$. Average amounts of aluminium (geometric mean) in pharyngeal tonsils of children is 20.29 $\mu g \cdot g^{-1}$ in Silesia Region and 22.98 $\mu g \cdot g^{-1}$ in Małopolska, and they are comparable with those observed in lungs [19]. This high concentration of aluminium in pharyngeal tonsils and lungs can have its source in the highly soluble aluminium compounds. Higher amounts of aluminium were observed in the skin, lymph node, suprarenal glands and parathyroid glands [19].

The average amount of aluminium of 20 $\mu g \cdot g^{-1}$ is 100-3,000 times higher than the amount observed in blood plasma [28, 29]. Aluminium in hair is found in the amount of about 2.1-5.2 $\mu g \cdot g^{-1}$ and in infant's hair – 0.154 $mg \cdot g^{-1}$ [29]. Al concentration in femur head – 15.36 $\mu g \cdot g^{-1}$ in women and 13.80 $\mu g \cdot g^{-1}$ in men was observed by Brodziak et al., and this value is similar to aluminium concentration in pharyngeal tonsils from children exposed and unexposed to tobacco smoke: arithmetic mean of contents of aluminum in pharyngeal tonsils from exposed girls was 15.94±8.08 μg/g, in unexposed girls was 14.11±5.08 μg/g, in exposed to tobacco smoke boys – 16.68±11.17 μg/g and unexposed boys 18.08±10.56μg/g was observed [19, 26].

Aluminium concentration in pharyngeal tonsils (20 $\mu g \cdot g^{-1}$ and the amount of aluminium in the air – 82.5 $\mu g \cdot m^{-3}$) create a coefficient of 0.25 [25, 30]. This means that about ¼ quantity of aluminium present in the stream of inhaled air can be incorporated to pharyngeal tonsils. The location and the way of inhaling the air through the nose constitute the so-called critical way in the migration processes of aluminium to a child's body. Thanks to this fact the accumulation of aluminium in the heart and muscles is far less – 1.2±0.8 $\mu g \cdot g^{-1}$ of dry matter, in case of bones it amounts 3.3±2.9 $\mu g \cdot g^{-1}$ of dry matter, for liver – 4.1±1.7 $\mu g \cdot g^{-1}$ of dry matter, spleen 2.6±2.1 $\mu g \cdot g^{-1}$ of dry matter, brain 2.4±1.3 $\mu g \cdot g^{-1}$ of dry matter, and lungs 43±43 $\mu g \cdot g^{-1}$ of dry matter [31, 32].

Conclusions

1. Aluminium contents in pharyngeal tonsils is related to the emission of dust containing aluminium and differs according to site habitants and gender.
2. Pharyngeal tonsils can be used as a biological sample for bioindication of aluminium in the environment.

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