Serum Aluminium in Alumina Exposed Workers

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Abstract

This study was performed after skepticism occurred in 1994 when alumina, or aluminium oxide, was thought to be the cause of sickness and death for certain workers at the Northern Industrial Park, Lumphun province, Thailand. Zeeman-graphite furnace atomic absorption spectrometric method has been developed to quantify the aluminium (Al) levels in the serum of 399 workers and 500 blood donors. The results showed that Al levels in the directly (n = 62) exposed workers was significantly different from the indirectly exposed (n = 130) and non-exposed (n = 207) workers and donors. However, symptoms found in the directly exposed workers were not significantly different from those in the indirectly exposed workers. In addition, a high percentage of headache and fatigue found in both directly and indirectly exposed workers suggested that more than one hazard could be involved in the incidence of alumina.

Key word : Alumina, Aluminium, Directly and Indirectly Exposed Workers

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At the beginning of 1994, the body of a deceased 21 year old Thai woman was sent to the authors' department for an autopsy in order to find the cause of death. She had been a worker at a particular factory located in the Northern Industrial Park, Lumphun province, Thailand. Her relatives and the doctor who treated her suspected she died from a chronic exposure of alumina during her work[1]. She

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had a chronic headache, convulsions, and two head surgeries before her death. No unusual causes of death were apparent from the autopsy. Blood, serum, urine, lung, brain and liver samples were collected and sent to the Department of Medical Science, Ministry of Public Health, Nonthaburee province, for aluminium (Al), lead (Pb) and cadmium (Cd) analyses.

There are approximately 87 factories located in the Northern Industrial Park in an area of 1,788 rais (approximately 720 acres) with over 16,000 workers. There were 4,200 male and 11,800 female workers in 1994. Most factories produced electronic accessories(2).

The analytical results demonstrated that the levels of Al, Pb, and Cd in the deceased woman's tissues were not found at toxic levels. It was concluded that the woman's sickness and death were not related to her occupation as previously suspected. So, the authors proposed this study and received funding to investigate the health impact of alumina exposure, related to the levels of aluminium in workers.

Alumina or aluminium oxide (Al_2O_3), MW 101.94, is a white crystal powder, water insoluble, but slowly soluble in an aqueous alkaline solution. It occurs in nature for example; bauxite, used as an adsorbent, desiccant, des abrasive as filler for paints and varnishes, as a ceramic material insulator (electrical), and in dental cements. Inhalation of a high concentration of alumina powder may be irritating to the respiratory tract. Fibrosis, emphysema, and pneumothorax have been reported in workers exposed to fumes arising from electric arc furnaces in which commercial abrasive Alundum (fusing bauxite) is made(3). The health impact of alumina exposure related to levels of aluminium in such workers has not been investigated. However, Al levels in workers exposed to Al fumes and dusts in Finland were higher than those in the non-exposed population(4).

Aluminium is a metal normally found in the human body but has been reported to be lower than 10 μg/L(5,6). The sources of Al in our body are from tap water, medication for peptic ulcers such as aluminium hydroxide, and also result from long-term kidney dialysis(7). It has been reported(8) that Al may cause "aluminosis" with symptoms of coughing, chest pain, and shortness of breath. Pulmonary fibrosis, convulsions, and encephalopathy have also been found.

The majority of aluminium (90%) in plasma is bound to transferrin(9). Only 4 per cent will be excreted *via* the kidneys, as urine(10). It has been assumed that an accumulation of Al may be a factor in the cause of Alzheimer's disease, Parkinson's dementia, and Osteomalacia(11). The molecular mechanism of Al-induced Alzheimer's disease is being investigated(12).

Patients with chronic Al intoxication had serum Al over 100 μg/L(13). McCarthy et al, suggested that this high level of Al was a reliable index of osteomalacia in dialysis patients because after treatment with desferrioxamine, a metal chelator, serum Al decreased as the patients were recovering(14,15).

Measurement of Al in serum is a tedious task. Most of the Al analyses use a graphite furnace atomic absorption spectrometer (GFAAS) to measure the Al levels(16-18). The authors decided to develop our own Zeeman-GFAAS to quantify the Al levels in Thai blood donors. The data will be valuable for reference before analyzing the Al levels in the alumina exposed workers in the Northern Industrial Park. Correlation of Al levels and adverse effects on health were also investigated.

MATERIAL AND METHOD

Apparatus and chemicals

An atomic absorption spectrometer equipped with a graphite furnace (Varian Spectra A800Z) and Zeeman background correction system were used in conjunction with a programmable Varian autosampler. The system was controlled by SpectrAA software and OS/2 program for data processing.

A hollow cathode lamp and platform graphite tubes were purchased from Varian, in Australia. Argon gas 99.999 per cent was ordered from Lanna Industrial Gas Ltd., Chiang Mai. The standard aluminium solution (1 g/L) and all chemicals were purchased *via* a local agency. Ultrapure deionized water was produced from a Maxima, ELGA model UF (Elga Ltd, England) in the equipment center.

Glassware and plastic ware preparation

To avoid aluminium contamination, all of the glassware was washed and soaked in a 20 per cent nitric acid solution for two nights. Then it was rinsed with ultrapure deionized water and soaked again, now in 0.1 per cent EDTA solution overnight. Finally, it was rinsed with ultrapure deionized water, dried, and kept clean before being used. The plastic ware Eppendorf tips, were also washed and soaked in nitric acid and EDTA solutions for 2 to 3 hours.

Control serum and modifier

Pool A from the University of Surrey, UK, and Seronorm™ from Norway were used as a known control serum. This was diluted with 0.2 per cent magnesium nitrate in 0.05 per cent Triton X-100, at the ratio of 1 to 3.

Obtaining serum and questionnaire

Serum was obtained from 500 blood donors at Maharat Nakorn Chiang Mai Hospital. Positive HIV, hepatitis and hemolytic serums were discarded. Serum from 399 workers, 192 exposed, 207 non-exposed, from 2 factories at the Northern Industrial Park were obtained during an annual health check up by teammates of the Chief Medicine Officer, Lamphun Province Health Office.

The workers at a factory that uses alumina in the process of their productivity were defined as the exposed group. The 192 exposed workers were separated according to their specified jobs into directly (n = 62) and indirectly exposed (n = 130) groups. Non-exposed workers (n = 207) worked at another factory where no alumina was used.

There were three sections in the health questionnaire used for the exposed group. Included in the first section was general information of the workers such as age, weight, height, gender, education, and domicile. The second section included the workers' work history such as duration, type, risk factors, and self-protection. The last section included a health history, in addition to data about workers' behaviors such as smoking, drinking, and taking various medications regularly.

Aluminium analysis

Serum aluminium was analyzed by the standard addition method in a platform graphite atomizer. The time and temperature program was modified from the method of Wang et al(19), Johnson & Treble (20), and Ruangyuttikarn et al(21). Sensitivity, precision, and accuracy of the method were determined using known control serum before analyzing unknown samples.

Thirteen per cent of the serum obtained from the exposed workers (25 out of 192 cases) was sent to be double checked at the Trace Element Laboratory, Robens Institute, University of Surrey, UK.

Data analysis

Statistical software SPSS 7.5 for Windows was used to analyze the data and investigate the correlation between aluminium levels and the exposed workers' health, and individual work histories.

RESULTS

Mean and Standard Deviation (SD) of serum Al in Thai blood donors, non-exposed, and exposed workers were not significantly different ($p>0.05$). However, the Al levels in the directly exposed workers was very significantly ($p<0.001$) higher than those Al levels in the indirectly exposed and non-exposed workers and the donors. The data are shown in Table 1.

Distribution of serum Al levels in blood donors was similar to the distribution of those Al levels in non-exposed workers. The curves were not normally distributed but skewed to the left. The incidence of serum Al levels in the directly and indirectly exposed workers was normally distributed with Mean and Median being very close.

The Al levels in both directly and indirectly exposed workers were not correlated to their symptoms of sickness. Most of the workers reported headaches and fatigue. Other symptoms included arthritis, rash, nervousness, diarrhea, dizziness, constipation, nausea & vomiting, anorexia, stupor, and bad dreams. Serum Al levels were also not significantly different considering age, gender, educational background, domicile, and length of employment. Most of the workers worked 6 days a week, 8-10 hours a day.

Sixty-five per cent of the workers between 21-30 years of age lived in the northern part of Thailand. Fifty per cent of them were single. The majority of the workers graduated from junior high school.

The workers specified their risk factors as dust, alumina powder, organic solvents, loud noise, bright light, chemicals, heat, and tar. Most of the workers utilized self-protection such as cloth masks and gloves. Organic solvents used were butyl alcohol, toluene, trichloroethylene, methyl ethyl ketone, acetone, and methanol. The chemicals used were plasticized D60, dioctyl phthalate, glycerin, PVB, and phenophthalene.

DISCUSSION

The high precision and accuracy of the modified method for serum Al analysis gave the authors confidence to analyze all of the 899 serum samples collected from blood donors and workers. Twenty-five serum samples of exposed workers selected randomly were sent to be analyzed at the UK, and showed similar results to ours. However, there were three

Table 1. Mean and standard deviation of aluminium levels in the serum of exposed (directly and indirectly), and non-exposed workers compared to blood donors.

Subjects	n	Serum Al (μg/L) (Mean ± SD)
Blood donors	500	8.5 ± 5.7
Exposed workers	192	10.8 ± 5.5
Directly-exposed workers	62	13.6 ± 4.5*
Indirect-exposed workers	130	9.4 ± 5.3
Non-exposed workers	207	7.9 ± 6.5

* $p<0.001$ using ANOVA and LSD Post Hoc tests

Table 2. Aluminium levels in the serum of Thai blood donors in this study compared to other studies.

References	n	Aluminium (μg/L)	Specimen	Country
Leung & Henderson 1982	28	2-14	Plasma	Canada[22]
Frech et al. 1982	11	1.6 ± 1.29	Blood	Sweden[23]
Monteagudo 1989	ND	<10	Serum	South Africa[5]
Wang et al 1991	63	1.62 ± 1.35	Serum	Canada[19]
Johnson & Treble 1992	13	4.8 ± 8.9	Serum	Canada[20]
Al-Saleh & Shinwari 1996	533	23.2 ± 15.3	Serum	Saudi Arabia[24]
Lee et al 1996	16	0.5-2.9	Serum	Singapore[25]
Sato et al 1997	113	2 ± 3	Serum	Japan[26]
The present study	500	8.5 ± 5.7	Serum	Thailand

ND = not indicated

samples that reported higher Al levels. It was suspected that contamination might have occurred during the transfer and transport process of those three serum samples. Although using Zeeman GFAAS to quantify serum Al is quite simple and not time consuming, the process of analysis needs great care to prevent contamination. Al contaminated environmental dust was avoided by permitting only authorized personnel into the analyzing room.

The average normal Al level in Thai people was a little higher than that found in other people such as Japanese, Canadians, Swedish, and South Africans, but not Saudi Arabians (Table 2). All used atomic absorption spectrophotometer to measure Al levels. It has been reported that contamination of Al in drinking water and food affects serum Al levels in normal people[27]. In Thai kitchens, Al pots, pans, and utensils are widely used as they are light, inexpensive, and easy to clean. This might contribute to the cause of higher serum Al levels in Thai people compared to Europeans and the Japanese. High levels of Al in Saudi Arabia students[24] was also indicative of dietary and drinking water in a school in the north of Saudi Arabia. In addition, it has been reported that Al utensils contribute to Al accumulation in patients with renal disease[28]. Corrosion of Al in several brands of soft drinks has also been reported[29].

Rogers and Simon[30], reported that past consumption of foods containing large amounts of Al additives differed between people with Alzheimer's disease and controls, suggesting that a dietary intake of Al might affect the risk of developing this disease. There are several studies indicating Al is neurotoxic [31,32], hematotoxic[33,34], and cytotoxic[35]. It may also interfere with bone formation[36] and sperm quality[37].

Although a significant increase of Al levels in the directly exposed workers found in the present study was very interesting, when compared to the levels of the exposed to non-exposed workers, those levels were not different. de Kom et al[38] also found that Al levels in workers at bauxite mines were not different from those at a wood processing plant.

Exposure to a solid form of alumina like ceramics(39), synthetic auditory ossicle(40), or a dental implant(41) is not toxic, but exposure to alumina fumes is toxic(3) to the respiratory tract. Chronic bronchitis might result(42).

There were similar symptoms occurring in both directly and indirectly exposed workers in the present study. Most of the workers reported headaches and fatigue even though their average Al levels were significantly different in both groups. There might be other chemicals such as organic solvents involved in the sickness of the workers. Most organic solvents are neurotoxic, and likely to be an additional cause of headaches and fatigue.

Recently, several investigations reported that workers in the Al industry had occupational asthma(43), impairment of pulmonary functions(44), enhancement of pulmonary diseases with high levels of serum Al(45), cognitive difficulties(46), and neurobehavioral problems(47). It was also found that lifetime occupational exposure to aluminium was not likely to be an important risk factor for Alzheimer's disease(48). However, other studies found Al levels may be related to Alzheimer's.

Serum Al values in each group of people also depend on food intake, inhaled air, drinking water, drugs, and Al kitchen cookware. Solid alumina and alumina fumes also had different affects on workers. All of the involved factors in addition to serum Al levels, should be considered and studied further.

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ระดับอะลูมิเนียมในซีรั่มผู้ใช้แรงงานที่สัมผัสสารอะลูมิน่า

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การศึกษาครั้งนี้กระทำหลังจากเกิดเหตุการณ์ในปี พ.ศ. 2537 ที่มีการเจ็บป่วยและเสียชีวิตของผู้ใช้แรงงานในนิคมอุตสาหกรรมภาคเหนือ จังหวัดลำพูน โดยสงสัยว่าเกิดขึ้นเนื่องจากสารอะลูมิน่า หรืออะลูมิเนียมออกไซด์ ที่ผู้ใช้แรงงานสัมผัสในขณะทำงาน คณะผู้วิจัยได้พัฒนาวิธีซีแมน กราไฟท์ เฟอเนส อะตอมมิกแอบซอพชั่น สเปคโทรเมตรี ให้เหมาะสมเพื่อนำไปใช้วัดปริมาณอะลูมิเนียมในซีรั่มของผู้ใช้แรงงานจำนวน 399 ราย และของผู้บริจาคโลหิตจำนวน 500 ราย ผลการศึกษาพบว่า ระดับอะลูมิเนียมในผู้ใช้แรงงานจำนวน 62 ราย ที่มีการใช้สารอะลูมิน่าโดยตรง สูงอย่างมีนัยสำคัญทางสถิติ ($p<0.001$) แตกต่างจากระดับอะลูมิเนียมที่วัดได้ในผู้ใช้แรงงานจำนวน 130 ราย ที่สัมผัสทางอ้อม และผู้ใช้แรงงานจำนวน 207 รายที่ไม่มีการสัมผัสเลย อย่างไรก็ตามอาการเจ็บป่วยที่พบในผู้ใช้แรงงานที่สัมผัสโดยตรงไม่มีความแตกต่างไปจากอาการเจ็บป่วยที่เกิดขึ้นในกลุ่มผู้ใช้แรงงานที่สัมผัสทางอ้อม นอกจากนี้พบว่า อาการปวดศีรษะและอ่อนเพลียเกิดขึ้นกับผู้ใช้แรงงานส่วนใหญ่ทั้งที่สัมผัสทางตรงและทางอ้อม ทำให้คาดคะเนว่าสารพิษที่เป็นสาเหตุการเจ็บป่วยของผู้ใช้แรงงานน่าจะมีมากกว่าหนึ่งชนิดนอกเหนือจากสารอะลูมิน่า

คำสำคัญ : อะลูมิน่า, อะลูมิเนียม, ผู้ใช้แรงงานที่สัมผัสโดยตรงและสัมผัสทางอ้อม

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