Bull. Environ. Contam. Toxicol. (1996) 56:1-7

Bulletin of Environmental Contamination and Toxicology

Aluminum Content of Various Canned and Bottled Beverages

H. Aikoh, M. R. Nishio

Faculty of Science, Okayama University of Science, 1-1 Ridai-cho, Okayama City 700, Japan

Received: 30 December 1994/Accepted: 12 June 1995

The evidence implicating aluminum as a neurotoxin has been continuously mounting. Research with both animals and humans has linked aluminum with neurocognitive dysfunction and, in some cases, death (Rifat et al. 1990; Kristensen et al. 1990; Murray et al. 1991). Although the relationship between aluminum intake and Alzheimer’s Disease (AD) is still unclear, some experts have recently issued the strong warning that ' human exposure to aluminum should be limited' and suggested that, 'other than reducing head trauma, the only change in lifestyle that offers hope in reducing the incidence of Alzheimer’s is reduction in aluminum exposure' (McLachlan et al. 1991). Known sources of aluminum include air (Epstein 1987), antacids (Graves et al. 1990), antiperspirants (Graves et al. 1990), cosmetics (Walton 1992), dental preparations (McLachlan et al. 1991), food additives (Greger 1985), vaccines and allergenic extracts (McLachlan et al. 1991), tea (Kawachi and Pearce 1991), and water (Michel et al. 1990). In past years infant formulas and parenteral nutrients were found to contain excessive quantities of aluminum but this potential hazard has supposedly been corrected (Walton 1992).

One source of aluminum which has not yet been investigated is canned drinks. Visitors to Japan are struck by the tremendous proliferation of vending machines (5.46 million machines in 1993) which dispense many type of colas, juices, beer, 'sake' (rice wine), and other drinks (Japan Times 1993). Although there are a few drinks dispensed from these machines in glass bottles, the majority of drinks are in aluminum or steel cans. Research was needed to determine whether aluminum could be found in these canned drinks and, if so, how these levels might compare with aluminum levels which have been found by other researchers.

Correspondence to: H. Aikoh

MATERIALS AND METHODS

The aluminum content of beverages from aluminum and steel cans and glass bottles was examined. The beverages (all containers held 350 ml of beverage) tested included beer (both domestic and imported), tea (Japanese *'uron'* tea), cola, *Fanta* orange, and an isotonic drink (*Pocari Sweat*). Samples were taken for all of the beverages from each of the three types of containers. Water taken directly from the tap was also analyzed. The tap water was allowed to flow freely for two minutes before a sample was taken. All reagents used were of analytical grade. The volumetric flask used for the pretreatment of the samples was washed with pure water and immersed overnight in nitric acid (1 mole/l) for poisonous metal analysis. The flasks were again washed with pure water, 20 µl samples of all beverages were then placed in volumetric flask and diluted with pure water in order to attain a final volume of 50 ml. The dilution magnification was 2,500 times. The concentrations of aluminum were then measured by ion chromatography (ICP-MS, Model SPQ 6500, SEIKO). Blank tests were conducted using nitric acid instead of the sample beverages with these being treated as described above. Six different containers were used for each type of beverage and samples were taken from each of these six containers resulting in a total of six samples for each beverages from each type of container.

RESULTS AND DISCUSSION

The concentrations of aluminum in various beverages from different types of containers as well as tap water were measured by ion chromatography in order to determine whether aluminum, a metal which has been shown to be a neurotoxin and which has been linked to the pathogenic process which occurs in Alzheimer’s Disease, may be found in beverages sold in cans and bottles. The results are shown in Tables 1 and 2. Aluminum was found in all beverages tested. This was somewhat surprising as the expectation had been that aluminum would be found in beverages from aluminum and possibly steel cans (since aluminum is sometimes used in the manufacture of steel), but not in those beverages taken from glass bottles(with the exception of tea in which aluminum occurs naturally). The fact that aluminum was also found in non-tea beverages in glass bottles suggests possible contamination in the manufacturing process of the beverage. When viewed overall, the results show a clear downward progression with highest levels of aluminum found in beverages taken from aluminum cans. The concentrations found in steel cans were lower than those found in aluminum cans but higher than those from glass bottles. The lowest concentrations were found in beverages from glass bottles.

Table 1. Aluminum concentrations of various beverages from aluminum cans, steel cans, and glass bottles as measured by ion chromatography.

Samples	Aluminum cans (Mean, ppm±SD)	Steel cans (Mean, ppm±SD)	Glass bottles (Mean, ppm±SD)
Beer, Imported	0.111 ± 0.011	0.074 ± 0.002	0.061 ± 0.001
Beer, Domestic	0.053 ± 0.004	0.049 ± 0.001	0.035 ± 0.002
'Uron' Tea	0.165 ± 0.002	0.123 ± 0.001	0.156 ± 0.007
Cola	0.098 ± 0.001	0.074 ± 0.001	0.031 ± 0.002
Fanta Orange	0.092 ± 0.001	0.045 ± 0.001	0.028 ± 0.001
Pocari Sweat	0.036 ± 0.001	0.034 ± 0.001	0.016 ± 0.001
Tap Water		0.029 ± 0.002	

NOTE: Number of samples : 6 for each beverage from each type of container.

Table 2. Significance levels* for the differences between the aluminum concentrations found in the same beverage taken from aluminum versus steel cans, aluminum cans versus glass bottles, and steel cans versus glass bottles.

Samples	Aluminum vs. Steel cans	Aluminum cans vs. Glass bottles	Steel cans vs. Glass bottles
Beer, Imported	++	++	++
Beer, Domestic	+	++	++
'Uron' Tea	++	+	++
Cola	++	++	++
Fanta Orange	++	++	++
Pocari Sweat	++	++	++

++ : $p < 0.01$; + : $p < 0.05$

* Levels of significance found by performing t-tests.

When the individual beverages are considered, the same results were found. Table 2 represents data obtained by performing t-tests. As can be seen, all differences were significant at the $p < 0.01$ level with the exception of domestic beer and 'uron' tea where the difference between the aluminum concentrations in domestic beer in aluminum versus steel cans and 'uron' tea in aluminum cans versus glass bottles was significant at the $p < 0.05$ level. The highest concentration of aluminum was found in the ' uron' tea from aluminum cans (mean = 0.165 ppm) with this being 1.34 times that found in the 'uron' tea taken from steel cans (mean = 0.123 ppm). The concentration in the tea from the glass bottles (mean of 0.156 ppm) was similar to that taken from the aluminum cans. This finding of aluminum in the 'uron' tea was not surprising as tea is one of the few plants that accumulates aluminum; mature tea leaves may contain up to two to three percent aluminum (dry weight). The imported beer from aluminum cans (mean = 0.111 ppm) was found to have roughly 1.82 times the aluminum of the same beverages taken from glass bottles (mean = 0.061 ppm). Domestic Japanese beer from aluminum cans (mean = 0.053 ppm) had approximately 1.5 times the concentration found in that taken from glass bottles (mean = 0.035 ppm). The aluminum concentration in aluminum can cola (mean = 0.098 ppm) was 1.32 times that of colas from steel cans (mean = 0.074 ppm) and 3.13 times that taken from glass bottles (mean = 0.031 ppm). The aluminum can *Fanta* orange drink’s aluminum level (0.092 ppm) was 2.06 times that taken from steel cans (mean = 0.045 ppm) and 3.28 times that taken from glass bottles (mean = 0.028 ppm). The isotonic drinks in the aluminum cans, steel cans, and glass bottles were found to contain 0.036 ppm, 0.034 ppm, and 0.016 ppm of aluminum respectively.

Tap water was found to have an aluminum concentration of 0.029 ppm. As can be seen from Table 1, this aluminum concentration for tap water is lower than that found for all beverages tested in all types of containers with the exception of the *Fanta* orange and isotonic beverages taken from glass bottles. Aluminum was found in all samples tested including not only those from aluminum cans, but those from steel cans and glass bottles. The highest levels of aluminum were found in samples taken from aluminum cans. The means of these samples from aluminum cans ranged from a mean of 0.036 ppm (isotonic drink) to 0.165 ppm (Japanese 'uron' tea). The aluminum levels from samples taken from steel cans ranged from 0.034 ppm (isotonic drink) to 0.123 ppm ('uron' tea). Aluminum ranging from 0.016 ppm to 0.156 ppm was found in the beverages taken from glass bottles. The higher concentration of aluminum in beverages taken from aluminum cans suggest that aluminum may be leaching into the beverages which they contain. The effect of length of shelf life on concentrations of aluminum will need to be investigated in the future. The fact that aluminum was also found in the steel cans may possibly be explained by the fact that aluminum is used in the steel manufacturing process to reduce the oxides. The aluminum contained in the steel used in Japan for cans is reported to be approximately

0.003% or approximately 20 to 30 ppm. Contamination during the manufacturing process may explain the aluminum found in beverages from glass bottles. Clearly canned and bottled beverages can be a significant source of aluminum. In order to gain some insight into the significance of these levels of aluminum, the research involving aluminum in water supplies must be considered.

A number of studies have related elevated aluminum concentrations in drinking water to an increased incidence of Alzheimer's Disease (Michel et al. 1990; Flaten 1990). In a recent study by Michel et al. (1990), the aluminum levels in the drinking water studied ranged from 0.01 ppm to 0.16 ppm. The relative risk for probable Alzheimer's Disease at 0.10 ppm was 4.53 times greater than at 0.01 ppm. In an incidence study of presenile Alzheimer's patients in England, Martyn et al. (1989) found that the relative risk of Alzheimer's Disease in areas with aluminum levels of 0.11 ppm or more in the drinking water was 1.7 as compared with a relative risk of 1.0 in areas with levels of less than 0.01 ppm (Martyn et al. 1989).

Of particular concern are the relatively low residual aluminum concentrations at which an effect was found. Results from the present study found higher concentrations than found in the water supply studies mentioned above which have found a relationship between the incidence of Alzheimer's and aluminum concentrations. The tap water investigated in the current study was found to have an aluminum level of 0.029 ppm. Table 3 shows how the levels of aluminum in the beverages tested compare with the level found in the tap water.

Table 3. Levels of aluminum in various beverages compared to tap water.

Samples	Aluminum cans	Steel cans	Glass bottles
Beer, Imported	3.8 X	2.6 X	2.1 X
Beer, Domestic	1.8 X	1.7 X	1.2 X
'Uron' Tea	5.7 X	4.2 X	5.4 X
Cola	3.4 X	2.5 X	1.1 X
Fanta Orange	3.2 X	1.5 X	0.9 X
Pacari Sweat	1.2X	1.2 X	0.6 X

Only two beverages had aluminum concentrations lower than the tap water tested. The highest concentration in the current study ('uron' tea in aluminum cans, m=0.165 ppm) is approximately 1.5 times the 0.11

ppm level found by Martyn et al. (1989) and Michel et al. (1990) to be associated with increased relative risk of Alzheimer's Disease. Imported beer in aluminum cans was found to have the same level of aluminum concentration found to have been associated with an increased risk of Alzheimer's Disease. For people who depend on canned beverages as a significant source of fluid intake, the concentrations of aluminum consumed in this way can be considerable. Delonche and Guillard (1990) have hypothesized that metals, such as aluminum, may form stable complexes with asparatic and glutamic acids, cross the blood-brain barrier and be deposited in the brain.

The relationship between aluminum and Alzheimer's Disease is quite controversial. As has been pointed out by other researchers, some people may consume up to 1 gram of aluminum per day in the form of antacids (Epstein 1987) yet no association has been found between dementia and the use of antacids (Johnstone 1992). There is, however, evidence to indicate that aluminum may be more bioavailable when dissolved in water as opposed to being ingested in foodstuffs (Kawachi and Pearce 1991; Martyn et al. 1989). There are also several other factors which may increase the bioavailability of aluminum and these are of concern when considering the results of the current study.

REFERENCES

Delonche R, Guillard O (1990) Mechanism of Alzheimer's Disease: Arguments for a neurotransmitter-aluminum complex implication. Neurochemical Research 15: 1239-45.

Epstein SG (1987) Aluminum and health: an update on Alzheimer's Disease. Washington, DC: Aluminum Association.

Flaten TP (1990) Geographical associations between aluminum in drinking water and registered death rates with dementia (including Alzheimer's disease, Parkinson's disease and amyotrophic lateral sclerosis) in Norway. Environ Geochem Health 12: 152-167.

Greger JL (1985) Aluminum content of the American diet. Fd Technol 39: 73.

Graves AB, White E, Koepsell TD, Reifler BV, Van Belle G, Larson EB (1990) The association between aluminum-containing products and Alzheimer's disease. J Clin Epidemiol 43: 35-44.

Japan Times(1993) Vending machines on rise, selling drinks and neckties. 5 March.

Johnstone T (1992) Aluminum and Alzheimer's disease (letter). Canadian Medical Association Journal 146: 431-432.

Kawachi I, Pearce N (1991) Aluminum in the drinking water -- is it safe? Australian Journal of Public Health 15: 84-7.
Kristensen C, Ingmundson P, Vogel H, Robbins C, Borcherding S (1990) Aluminum intoxication and neuropsychologic dysfunction in chronic dialysis patients. Kidney Int 37: 305.
Martyn CN, Baker DJP, Osmond C, Harris EC, Edwardson JA, Lacey RF (1989) Geographical relation between Alzheimer's disease and aluminum in drinking water. Lancet 1: 59-62.
McLachlan DRC, Kruck TP, Lukiw WJ, Krishnan SS (1991) Would decreased aluminum ingestion reduce the incidence of Alzheimer's disease? Canadian Medical Association Journal 145: 793-804.
Michel P, Commenges D, Dartigues JF, et al. (1990) Study of the relationship between Alzheimer's disease and aluminum in drinking water [abstr]. Neurobiol Aging 11: 264.
Murray JC, Tanner CM, Sprague SM (1991) Aluminum neurotoxicity: A reevaluation. Clinical Neuropharmacology 14: 179-185.
Rifat S, Eastwood MR, McLachlan DR, et al.(1990) Evidence regarding the effect of prolonged aluminum exposure on cognitive function. Lancet 336: 1162-1165.
Walton L (1992) Alzheimer's disease and the environment (editorial). Journal of the Royal Society of Medicine 85: 69-70.