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Aluminum Level in Infants' Powdered Milk Based Formulae

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ABSTRACT

Aluminum level (Al) in infant formula was determined to postulate its public health significance and suggesting recommendations to avoid such contamination. Hence, fifty random samples of infants powdered milk based formulae were collected from different markets and pharmacies in Assiut Governorate, Egypt. These samples were digested and Al level was detected by using HR-CS (High Resolution Continum Source Atomic Absorption Spectrophotometer) and compared with Maximum Permissible Limit (MPL). About 90% of examined infant formula samples containing Al with an average value of 0.145 mg/L and 8% of samples were above the MPL.

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Introduction

Infant formulas are milk-based feeds for infants developed as alternatives to breast milk. Though cow's milk is the main ingredient of many infant formulas, they are sophisticated products designed to meet the specific nutritional needs of children from babies born pre-term through to infants of several years of age. There are also non- cow's milk-based formulas, often been made from soya, which used for infants with intolerances or allergies to cow's milk. Despite the benefits of infant formulas as a major source of food for infants, the presence of contaminants such as heavy metals may pose health risks to children. It has been reported that children are more susceptible to exposure (Tripathi *et al.*, 1999) because of their greater intestinal absorption than adults, and a lower threshold for adverse effects (Cambra and Alonso, 1995). These pollutants may arise from the raw materials used in production, poor quality production processes, adulteration of infant foods and bad practices by mothers during their preparation and handling (Fein and Falci, 1999). The presence of heavy metals in dairy products may be attributed to exposure of lactating cows to environmental pollution or consumption of contaminated feeding stuffs and water (Carl, 1991; Okada *et al.*, 1997). Moreover, raw milk may be exposed to contamination during its manufacture (Ukhun *et al.*, 1990; El-Batanouni and Abo-El-Ata, 1996). Contamination may also occur from the use of aluminum utensils and cans in milk and dairy products (DeVoto and Yokel, 1994).

Aluminum is the most abundant metallic element and constitutes about 8.13% of the earth's crust. It is the third most abundant element in nature after oxygen and silicon. Elemental aluminum does not occur in its pure state; it is always combined with other elements (e.g., hydroxide, silicate, sulphate, phosphate). It is present in soils and clays, minerals and rocks, and even in water and food. Its compounds are used in food industry such as food additives, in baking powder, processed cheese, meat products, cooking, and storage utensils. Moreover, aluminum compounds (aluminum sulphate) are also used for particle sedimentation in water-treatment. Generally, infants fed formula made with tap water are at the highest risk from metals contaminating the water supply (Soylak *et al.*, 2006; Saracoglu *et al.*, 2007). Furthermore, it is one of the toxic elements that accumulate in lungs, liver, kidney, thyroid and brain. It has been reported that infants are extensively vulnerable to exposure of aluminum because of their immature renal

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systems and exhibit a narrow tolerance to this non-essential element (Bougle *et al*., 1997; Tuzen and Soylak, 2007). Such element is a potent neurotoxin; long-term feeding of aluminum-containing total parenteral solutions to preterm infants caused impaired mental development at 18 months (Klein *et al*., 1998). Also, excess aluminum in blood is selectively incorporated into the bones of infants, resulting in a weakened bone structure (Bernardo *et al*., 2010). Fortunately, urine and faeces is the normal pathway for excreting aluminum from the body when ingested in food or being drunk in liquids (ATSDR, 2008). Consequently, in humans with renal insufficiency, the kidney is unable to excrete excess of aluminum from the body resulting on more health hazard. Extensive literature reviews cast no doubt that it has a neurotoxic effect and play a factor in Alzheimer's disease, a very common cause of dementia. Also, different experimental studies showed that the nervous system is a sensitive target of aluminum toxicity (Fattoreti *et al*., 2004; Gupta *et al*., 2005).

There has been a long and significant history documenting the contamination of infant formulas by aluminum (Fernandez-Lorenzo *et al*., 1999; Navarro-Blasco and Alvarez-Galindo, 2003; Kazi *et al*., 2009) and consequent health effects in children (Hawkins *et al*., 1994; Bougle *et al*., 1998).

Therefore, this study put a focus on the level of aluminum contaminating infant powdered milk based formulas and associated health risks.

Materials and methods

Collection of samples

A total of 50 random samples of infants powdered milk based formulae were purchased from different markets and pharmacies in Assiut Governorate, Egypt during the period from June 2013 to October 2013. These samples were collected in their original containers and packets, and transported to the laboratory.

Washing procedure

Washing is an important process to avoid contamination especially when trace element or heavy metal are to be analyzed. The tubes and glass wares were soaked in water and soap for two hours and rinsed several times with tap water. They were rinsed once in distilled water, and once with acid then air-dried in an incubator away from contamination or dust.

Preparation of collected samples

One gram of infant formula was transferred into clean and acid washed screw-capped digestion tubes. All digestion tubes were identified for examination.

Digestion procedure

Organic matter and other components present in the samples would interfere with the analytical process unless they were removed. Organic matter are usually removed by some form of oxidation using oxidizing acids, then aluminum level was determined by Atomic Absorption Spectrophotometry (Reilly, 1991).

Procedure

The procedure was carried out in the Central Laboratory at Faculty of Veterinary Medicine, Assiut University, where 1g of infant formula sample was weighed into digestion tubes and 5 ml of concentrated Nitric acid (HNO3 70%) were added and kept overnight. Then, the tubes were capped snugly, heated in a water bath at 80°C for 6 hours and cooled at room temperature. The water and any droplets near the cap were wiped from tube, and the cap was carefully removed without touching its edge and placed, top down, on a clean surface. Contents were diluted to 10 ml mark with distilled water, tubes were capped, shaked, filtrated and let to stand until analysis by Graphite-furnace Atomic Absorption Spectrometric (GFAAS) method.

Preparation of blank solutions

One ml distilled water was added to 5 ml Nitric acid (70%), left overnight and then digested in water bath at 80°C for 6 hours and cooled at room temperature. Then the contents were diluted to 10 ml mark with distilled water and then filtrated. The blank solution was analyzed by Atomic Absorption Spectrophotometer and any metal residues were subtracted from the results obtained at each corresponding procedure.

Analysis on Graphite Atomic Absorption Spectrophotometer (GAAS)

The analysis was carried out at Analytical Chemistry Unit (ACAL), Department of Chemistry, Faculty of Science, Assiut University, Egypt. All filtrated samples of infant formula and milk powder samples were analyzed for their Al concentration by using HR-CS Atomic Absorption Spectrophotometer (High Resolution Continum Source Atomic Absorption Spectrophotometer).

Results

Results are summarized in tables 1, 2 and 3.

Table 1. Incidence and level of Aluminum in infant formula samples

No. of Examined samples	Positive samples		Concentration of Al (mg/L)		
	No.	%	Min.	Max.	Average
50	45	90	0.001	0.902	0.145

Table 2. Comparison of Aluminum level in infant formula samples with Maximum Permissible Limit (MPL) stated by FAO/WHO (2007).

MPL (mg/L)	Within permissible limit		Over permissible limit	
	No. of samples	%	No. of samples	%
0.4	46	92	4	8

Discussion

The data presented in Table 1 showed that 45 (90%) out of 50 examined infant formula samples were +ve for the presence of aluminum, while 5 (10%) were below the detectable limit of the device. The minimum level was 0.001, the maximum was 0.902, and the average value was 0.145 mg/L.

The average aluminum value of the obtained results was

Table 3. Comparison of Acceptable Daily Aluminum Intake (ADI) with that estimated from consumption of 200 ml reconstituted infant formula (EDI) stated by FAO/WHO (1989).

Average value (mg/L)	Daily intake from consumption of 200 ml reconstituted infant formula		
	*ADI	**EDI (mg/day/person)	%
0.145	1	0.029	2.9

*ADI: Acceptable Daily Intake.

**EDI: Estimated Daily Intake.

in harmony with that demonstrated by Fernandez-Lorenzo *et al.* (1999). However higher range of aluminum levels indicated by Kazi *et al.* (2009); Burrell and Exley (2010); Abd-El Aal (2012) while the results postulated by Biego *et al.*(1998); Chuchu *et al.* (2013) were extremely lower.

The high mean levels of aluminum in the examined infant formula samples may be attributed to migration of this element from packaging materials into milk products (Rajwanshi *et al.*, 1997) or from the chemicals used, machinery and dust particles (Navarro-Blasco and Alvarez-Galindo, 2003). Most of manufacturers use containers lined with aluminum based composite and have a tear-away aluminum foil seal between the powder and plastic lid. Others may use cardboard containers and powder is contained in aluminum foil-based pouches inside these boxes which may represent opportunities for contamination by aluminum (Shafer and Siefert, 2006). Thus, preterm infant formulae are regarded as a potential source of aluminium exposure.

The aluminum content of infant formulae was not significantly different to historical values. This lack of improvement in lowering aluminum content may be attributed to either that manufacturers are not monitoring aluminum content of their products or that the manufacturers are not concerned at these levels of contamination (Burrell and Exley, 2010).

Neonates are more susceptible to toxic effects of aluminum, because there are considerable variations in absorption, distribution, metabolism and excretion of this toxic element in neonates (Bohrer *et al.*, 2002).The high level of aluminum intake in infants, avoids the intestinal barrier and the renal immaturity of newborns impairs its elimination, while infants, especially preterm neonates, display a narrow tolerance to aluminum. Also, their gastric pH is ranged as pH 6–8, and the availability of toxic elements are more at this pH. The toxic effects of these elements are partly due to direct inhibition of enzymatic system and also to the indirect alteration of the essential metal ion-equilibrium. As a consequence their biological availability could be inhibited and damage to the cell membrane could occur by the disruption of ion transport across it (Campbell *et al.*, 2004; Sipahi *et al.*, 2006). Aluminum is now being implicated as interfering with a variety of cellular and metabolic processes (AAP, 1996). It may also cause bone disorders but the critical level of aluminum loading that results in bone disorders is not known (ADA, 2000).

The maximum permissible limit for aluminum in infant formula should not be exceeding 0.4 mg/kg as stated by FAO/WHO (2007). The results presented in Table 2 revealed that 4 (8%) out of 50 examined samples of infant formula were above MPL for aluminum and 46 (92%) samples were within the value of MPL for aluminum. The estimated daily intake of aluminum from consumption of 200 ml of reconstituted infant formula was 0.029 representing 2.9 % (Table 3).

The chemical composition of canned milk, as a product for long term storage, depends not only on the concentrations of raw milk components and on its treatment, but also on the mode of packing, quality of the packing materials and on the conditions and time of storage (Tchekulayeva *et al.*, 1981). Tinned can composition is tin 98.8%, small amount of lead beside soldering of seams with the help of lead-containing paste, copper, cadmium, aluminum from the Al-foil cover and some other metals, and due to the nature of their manufacture could be capable of participating in electrochemical transformation (Arvanitoyannis, 1990). The infant formulae showing the highest levels of aluminum are those with additives, such as calcium salts and soy protein, which contain aluminum as a contaminant (Ikem *et al.*, 2002).

The present study revealed that infant formulas contain aluminum element in variable concentrations above the toxicity levels. Therefore, more attention and concern should be denoted to avoid the sources of contamination to lower aluminum content.

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